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XII.

# AN INVESTIGATION OF THE MODE OF ACTION OF SHIP-FORMED SOLIDS ON THE WATER IN WHICH THEY MOVE, AND OF THE MODE OF ACTION OF THIS WATER UPON THEM, DETERMINING THE CAUSES OF THE SQUATTING OF VESSELS AND OF THEIR INCREASING RESISTANCES AS THE WATER SHOALS BELOW A CERTAIN DEPTH.

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In the May number for 1892 of this Journal, page 281, is an extract from a paper by Mr. W. H. White, the distinguished Chief Director of Naval Construction for the Admiralty, read before the Institution of Naval Architects during the spring session of 1892, concerning the influence of shoal water on the speed of vessels.

Mr. White gives several illustrations of this influence, as shown by recent performances of large high-speed steamers of the British Navy, but the differences of speed relatively to power applied in the cases he cites are too small to be confidently relied on. The writer, judging from an extensive personal experience in

such trials, and having regard to the manner in which the speed was ascertained in the particular cases given, is of opinion there was a probable error of about 5 per centum, which would be about five-sixths of a knot at the average experimental speeds, a quantity more than sufficient to cover the supposed difference due to the shoaling of the water.

There is great difficulty, giving credit for absolute honesty of purpose and for much care in obtaining accurate data, in determining the exact speeds of fast vessels over short distances. The continuously varying and unknown conditions of wind, tide and immersed surface of vessel; the want of trained and perfectly capable observers, a principal qualification of whom is a strong desire to have exact results for their own professional use; the few times the vessel is run over the base; the unavoidable errors in "timing," which, though small absolutely may be relatively large; etc.; all cause reasonable doubts of the exactness of the final results, rendering them uncertain and unsatisfactory when the differences to be determined are small.

Nor is the speed the only factor in the case, the indicated horses-power developed by the engines must be simultaneously measured, and, for strict accuracy, the fractions of this power applied to the propulsion must be known; that is to say, the losses of useful effect due to the power required to work the unloaded engines; to overcome the friction of the load; to overcome the surface resistance of the helicoidal surfaces; and expended in the slip of the screw; must be ascertained and deducted from the indicated horses-power before the power applied to the propulsion of the vessel can be known; yet without this last factor, no certainty attaches to the speed deduction. The literature of engineering is full of errors, and comical ones too, made by assuming the indicated horses-power developed by the engines to be the power applied to the propulsion of the hull, whereas, it is not only not this power but this power is not a constant fraction thereof, nor so large a fraction as to make the difference negligable. The power propelling the hull varies from 50 to 80 per centum of the indicated power, yet this enormous difference in the fraction is ignored.

There is, too, a further disturbing cause in the want of knowledge of the ratio with which the resistance of the vessel increases relatively to its speed. At high speeds, even for large vessels, this ratio greatly exceeds that of the square of the speed. How, then, in view of all these variable and unknown conditions, each capable of largely influencing the final result, can confidence be attached to deductions where only small differences are concerned? Some of these conditions may act in opposite directions and neutralize each others' effect; they may also act in the same direction and correspondingly exaggerate their effect; nevertheless, the general facts have been known as long as vessels have been navigated, that their resistance, after a certain depth of water has been reached, increases by farther shoaling, and that this depth depends on the size and speed of the vessel; but what that depth is for any particular size and speed of vessel has never been ascertained.

The cases cited by Mr. White are very interesting, and will have the effect, from his eminent position and great attainments, to bring a long neglected but very important subject to the notice of the world—probably all he expected from them. He evidently placed but little dependence on the speeds of the vessels he mentioned, although these speeds were the sole foundation for his belief in the enormous influence due to shoal water, even when its depth was from twice to thrice the vessel's draught of water, because he utters a fervent wish for some means to obtain them with exactness, and hopes Mr. Froude may be successful in contriving a pressure gauge for that purpose, a wish and a hope in which all naval architects and engineers will join him; but the writer has not much expectation in that direction; he has, himself, tried several kinds of such gauges, which, though promising, proved too delicate and needed too careful adjustment and correction for use on board ship under the ordinary conditions of practice. The only perfectly satisfactory speed register the writer ever found was the helicoidal one devised by him and used in the experiments with the common and the steering screws of the United States steamer *Nina*. It met, in that case, every requirement with absolute certainty.

Mr. White attempts no explanation of the causes producing these phenomena, but states that the subject has occupied his mind and must be dealt with. The writer has long known the facts, and years ago ascertained to his own satisfaction the causes of the phenomena in question by means of progressive trials made with small vessels driven at very high speeds proportionally to their size, in water of different depths but always shoal enough to produce the effects of shoaling. As the matter, owing to the enormous increase in the size and speed of steamers, has attained an importance which compels consideration, he has in this paper, at the request of some professional friends, given the results of his experiments and investigations in the form of a description of the manner in which ship-formed solids act upon the water in which they move, and of the manner in which the water acts on them, together with the deduced laws producing the phenomena.

When a vessel floats freely in smooth water, there is neither elevation of the latter at the bow nor depression of it at the stern, relatively to the general water level. The water presses the immersed surfaces of the vessel at right angles to them, and as these pressures, when reduced to opposite sides of any plane assumed across the vessel in any direction and limited by the surfaces of the latter, exactly counterbalance each other, the vessel, relatively to the water, remains at rest, let the form of its immersed solid be what it may.

If, however, the surface of the water, instead of being smooth, is undulating or in waves, there will be continual changes in the height of the water columns supporting the vessel, the pressure upon whose surfaces being no longer exactly equilibrated, the vessel will yield in the direction of the greatest pressure. Supposing the air perfectly calm, the vessel will, except under a certain condition, describe short paths in the direction of pressure changes. For equal differences of opposing pressures per unit of surface, the vessel will move different distances according to its different resistances per unit of surface in the direction of the unbalanced pressure. It will move farther when the unbalanced pressure is from aft to fore than when that pressure is from fore

to aft, and farther in either of these directions than when the unbalanced pressure is transverse the vessel.

The condition referred to is that the inertia of the vessel horizontally is too great to be overcome by the differences of pressure in the short intervals during which they act.

Supposing the inertia horizontally not to be great enough to produce this effect, and as the undulations are symmetrically vertical, the vessel would continually move forward in the direction of its keel by the action of the waves alone. This phenomenon is recognized by seamen, who have ascribed the forward movement of the vessel in such a case to what they graphically call "*the heave of the sea.*"

The differences of pressure transverse the vessel, first on one side and then on the other, exactly balance, as the resistances of the vessel are equal in those directions; but as the resistances of the vessel are unequal in its fore-and-aft direction, being less in the fore than in the aft, it will continually move farther in the forward than in the aft direction.

The portion of a vessel forward of its greatest immersed transverse section is called the "fore body," and the portion abaft this section is called the "aft body;" and in properly modeled vessels these two portions are of wholly dissimilar forms corresponding to the entirely different functions they perform in reducing the forward resistance of the vessel. The elementary form of the forward body is that of a wedge with sides equally inclined to its back and having its edge vertical. The stem of the vessel is the edge of this wedge, and the greatest immersed transverse section is the back. The elementary form of the aft body is also that of a wedge whose back is the greatest immersed transverse section of the vessel, but whose edge is horizontal and situate at the water line. Only the lower side of this wedge is inclined to the back, its upper side being at right angles thereto, and corresponding with the level of the water in which the vessel floats.

The various modifications, many of them being merely the fanciful notions of ignorant ingenuity, given in practice to these elementary forms, are mainly to meet the practical requirements

of construction, or for the purpose of giving certain qualities called "seaworthiness" when the vessel moves amid waves, but they scarcely affect its direct resistance when moving forward in smooth water. For illustration, what is called the U bow has the same resistance as what is called the V bow, these letters showing roughly the forms of the transverse sections of the fore body, but the V bow makes the vessel much drier at sea by throwing the wave water outwards. Also, the slight inflections, curvatures and other variations often given to the water lines or horizontal sections of the fore body, have no other effect than to slightly increase the wetted surface and therefore correspondingly the resistance of the vessel.

If a vessel be cut across at its greatest immersed transverse section, and the fore body alone driven through the water, the section in conjunction with the speed will leave behind it a cavity in the water, and the form of this cavity is the proper form for the aft body if the purpose be to merely equalize the statical pressure of the water on both sides of the section, thereby reducing any minus pressure aft to nothing. The form of the lower side of the cavity will vary for every speed of vessel, the cavity itself elongating as the speed increases. But, if the aft body be made of this form, although the resistance of a negative water pressure at the aft body will be avoided, the vessel will not obtain from the water filling this cavity any of the force expended by the fore body in displacing the water. To regain part of this force, the aft body must be made longer than the cavity, and the longer it is the more of the force will be recovered. The practical limit to this, however, is that the addition of length to the aft body increases its wetted surface, adding correspondingly to the resistance of the vessel. For minimum resistance, the greater the speed of the vessel the longer should be its aft body, and this length of aft body is one of the most potent factors in determining the resistance of the vessel. The resistance due to the aft body, exclusive of the resistance of its wetted surface, is not governed at any speed of vessel by the law of the proportionality of the resistance to the square of the speed. That law applies only to the resistance of the fore

body, and applies to it at all speeds of vessel. The resistance of the same fore body is always in the ratio of the square of its speed, let the speed be what it may, other things remaining constant. The increased resistance of the vessel as a whole above this ratio, at increased speeds, is due entirely to the action of the aft body.

The statement that the resistance of the fore body alone is, at all speeds, in the ratio of the square of the speed, is, of course, understood to be limited to speeds above which the vessel rises bodily in the water, a phenomenon that appears whenever the direct resistance of the vessel becomes greater than the weight of its displaced water. As each doubling of the speed of the vessel, *ceteris paribus*, increases its resistance at least four times, while its weight remains constant, obviously there is a speed at which the vessel will rise in the water, thereby decreasing its greatest immersed transverse section, displacement, and wetted surface, and correspondingly decreasing its resistance; the lighter the vessel per square foot of its horizontal projection, the less will be the speed at which its lifting occurs. The vertical sections of the fore body should be made such as to present an inclined or bateau surface to the water, and thereby assist the lifting movement. According to this view, the longer the fore body the flatter will be the inclined plane formed by the vertical sections, and the less will be the speed required to produce the lifting.

The application of this principle is limited to very high speeds proportionally to weight of vessel per square foot of horizontal projection, but such speeds have been attained in the case of torpedo boats. The fore bodies of all vessels designed for very high speed should be formed so as to obtain as much benefit as practicable in this manner.

Increasing the length of fore body, even when low or moderate speeds are employed, decreases the resistance other than that of the wetted surface, owing to the fact that the water displaced by the fore body is raised above the general water level, and that for a given vessel and speed the height to which it will be so raised is proportional to the length of the inclined side of the

fore body. To maintain this water at a double height involves a quadruple expenditure of force. From the gain thus obtained must, however, be subtracted the loss due to the increased wetted surface, so that within certain speeds lengthening the fore body does not lessen the resistance, while at greater speeds it does.

The water displaced by the fore body of an advancing vessel, rises vertically and forms a column in contact with the fore body, the top of the column being above the general water level while the bottom is at the level of the rabbet of the keel of the vessel. The pressure of this column on its base is, of course, greater than that of the surrounding water on an equal base in the same horizontal plane passing through the rabbet of the keel. Meanwhile, by reason of the same advance of the vessel, a cavity is left in the water abaft the greatest immersed transverse section. This absence of water at the aft body causes a less pressure to be there upon the horizontal plane passing through the rabbet of the keel than that of the surrounding water. Now the important questions to be answered are: How is this cavity to be filled? Whence comes the water filling it, and by what route; and due to the action of what force? The cavity will be filled from its bottom by water flowing into it vertically, because the bottom is the part of the cavity where the greatest unbalanced pressure exists. The movement of the water is necessarily vertical because the unbalanced pressure producing it is vertical, and the movement must be in the direction of the pressure. The water filling the cavity comes in a straight line from the column of greatest pressure, because, in an indefinite mass of water, there is nothing to deflect the pressure; this straight line will be the direction of the keel of the vessel, and the movement will be horizontal, because the superincumbent fore body prevents any vertical movement until the cavity is reached. The purely horizontal movement of the water will, therefore, be from the front of the fore body to the greatest immersed transverse section of the vessel, and the upper surface of this stream will be at the level of the horizontal plane passing through the rabbet of the keel, and the center of the movement will be at, and have the direction of, the keel. The water filling

the cavity behind the greatest immersed transverse section, must, therefore, be water lying immediately below the horizontal plane passing through the rabbet of the keel, which water is forced in the direction of least resistance (the cavity) from the place of greatest pressure (the column of water in front of the fore body raised above the surrounding general water level by the advance of the vessel and consequent displacement of water there). The water filling the cavity is not the water displaced by the advance of the vessel. The whole of that water is raised by the fore body above the general surface and spreads out, by gravity, over it. No water lying below the level of the horizontal plane passing through the rabbet of the keel can be directly displaced by the vessel, but this water will inevitably be put in horizontal movement beneath the horizontal projection of the fore body by the difference of pressure upon it there and abaft the greatest immersed transverse section due to the advance of the vessel. The quantity of water thus moved from the forward to the after side of the greatest immersed transverse section in a given time is equal to the product of the area of that section into the length passed through by it during the given time. The displacement of the vessel has no relation to this quantity of water.

The faster the vessel goes, the greater is the elevation of the water at the fore body above the general water level, and this increased elevation, due to increased speed, is sufficiently great to make the resistance of the fore body alone increase in the ratio of the square of the speed; consequently, the greater the speed of the vessel the greater correspondingly is the unbalanced pressure which fills the cavity with water, and the more rapidly, in the ratio of the square roots of the unbalanced pressures, will the filling proceed; but the greater the speed the longer too in direct ratio is the cavity to be filled, so that when the speed of the vessel makes the cavity longer than the length of the aft body, the cavity *for that length* is not filled to the surface level—is only partially filled—and the aft body being thus correspondingly unsupported, squats. The squatting begins at the instant when the aft end of the cavity is at the aft end of the aft body, and in-

creases as the distance aft between the aft end of the cavity and the aft end of the aft body increases.

The cavity being formed by the greatest immersed transverse section of the vessel moving forward at a given speed, and being always entirely filled by water passed beneath that section, there follows that the quantity of water passing under the section in a given time is exactly equal to the quantity displaced by the section in the same time; and, moreover, the cross section of the stream of water thus passing under the greatest immersed transverse section will there have the form and dimensions of that section. The longer the cavity the longer will be the time of filling it.

When the depth of water between the bottom of the vessel and the ground, proportionally to the vessel's draught of water, is sufficiently great, there is no impediment to the transfer of the displaced water from one side of the greatest immersed transverse section to the other; but when that depth is not sufficiently great, or, in other words, when the lower portion of the horizontal stream of water comes in contact with the ground, impediments arise to its flow from the roughnesses and irregularities of the ground, and also from the too restricted cross section for the stream if the depth from bottom of vessel to ground be too small.

As the breadth of the stream of water passing beneath the greatest immersed transverse section to fill the cavity abaft that section is limited to the breadth of that section, and as the quantity of this water passing that section per unit of time is equal to the area of the section multiplied by its speed, the depth of the stream must be equal to the height of the greatest immersed transverse section, and this depth, for the same vessel, will be the same at all speeds in sufficiently deep water.

Supposing the greatest immersed transverse section to be a parallelogram, and the depth of the water in which the vessel moves to be sufficiently great, the depth of the horizontal stream of water passing beneath the lower edge of the parallelogram will be equal to the height of the parallelogram, and the force to produce the horizontal movement of this mass of water will be the pressure of a column of water of the height of the paral-

lelogram. As a consequence, the depth of water in the clear beneath the bottom of a vessel must be considerably more than its draught of water, probably twice as much, in order that the shoalness may not affect the speed of the vessel. For very high speeds of vessel, the depth of water from the surface should, probably, be about from three to four times the vessel's draught of water.

As a corollory to the foregoing, the depth of the water current flowing beneath the fore body in the direction from fore to aft, and having its upper surface at the horizontal plane passing through the rabbet of the keel, will be *nil* at the stem, and gradually increase until the greatest immersed transverse section is reached, when the depth will be equal to the vessel's draught of water at that section exclusive of keel. The bottom of this stream will be an inclined surface, and its upper horizontal surface will have the outline and dimensions of the horizontal projection of the fore body. The ordinates from the upper horizontal surface of the stream to its bottom will be proportional to the immersed transverse sections of the fore body at the ordinates. The speed of the fore body considered alone is not affected by the shoalness of the water. The enormous influence exerted upon the vessel's speed by shoal water is due wholly to the after body.

From the stem to the greatest immersed transverse section, the direction of the current of water moving beneath the fore body is wholly horizontal, and its depth there is a maximum, but after passing that section, this current has a continuously lessening depth, and its water has two distinct movements, one horizontally, the other vertically, and to the latter it owes its continuous diminution of depth. The horizontal current extends to the aft end of the cavity and is of uniform breadth from the greatest immersed transverse section until that end is reached. The water flowing upwards to fill the cavity is taken from this horizontal current.

When the depth of water is relatively small between the bottom of the moving vessel and the ground the stream has to be forced between the ground and the wetted perimeter of the

greatest immersed transverse section at an accelerated speed if the cavity is to be kept filled, and against the resistance produced by the roughnesses and inequalities of the ground. No additional force to give the needed acceleration is brought into action by the circumstances, and the consequence is that the cavity for the length of the aft body remains proportionally unfilled, the resistance of the vessel increases, its speed decreases, its trim alters, its propellers increase in slip and diminish in propelling efficiency, the stern squats and the bow rises.

The increased resistance of the vessel in shoal water is due exclusively to the aft body, by reason that the water, not being able to fill the entire cavity made by the advance of the vessel, during the time the aft body passes through its length, does not support that body, which necessarily drops until by meeting the water it finds such support. The increased resistance of the vessel is due to the increased inclination of the vessel thus given to it, and to the minus pressure thus caused against the aft side of the greatest immersed transverse section. The same causes also operate to diminish the propelling efficiency of the screw, if a screw be used.

The effect of shoal water upon the speed of a vessel propelled by a screw is much more marked than when the same vessel is propelled by the paddle wheel, because the propelling efficiency of the latter is not sensibly impaired by the want of water beneath the aft body. The increased resistance of the hull due to the shoaling will, of course, be the same with both kinds of propellers, but the effect in diminishing the speed will be less with the paddle wheel.

The influence of the proximity of the ground to the bottom of the vessel extends far below the depth of the stream of water required to fill the vacuity abaft the greatest immersed transverse section, as a stream, by the cohesion of its molecules with those of the adjacent still water, drags with it a large mass of water, though at continuously lessening speed as the distance continuously increases.

The speed of the vessel so greatly influences the performance in very shoal water, that a vessel which will ground aft at a cer-

tain speed will continue to float free at a less speed. In the case of grounding in very shoal water the stern touches long before the bow, supposing the vessel to have been "on even keel" just previous to the grounding. As with greater speed of vessel a proportionally greater quantity of water must pass beneath the greatest immersed transverse section per unit of time, and as the resistance of the ground increases in the ratio of the square of the speed, the quantity of water passing the section per unit of time decreases with the speed when the bottom of the vessel is in proximity to the ground.

The current flowing beneath the greatest immersed transverse section will, in the case of a vessel passing through water which, though shoal, is deep enough to leave considerable space between the ground and the bottom of the vessel, act so strongly on the ground as to thickly stir up the mud, if the ground be of that material, or to stir up sand or any loose substances lying upon the ground. Indeed the mud and sand coming to the surface in whirling masses of water in contact with the vessel, is an unfailing sign that the water is dangerously shoal.

All the phenomena above cited are intensified when the water not only shoals in the channel but the channel simultaneously narrows. In this case, other things equal, the trim of the vessel changes still more, the bow becomes more raised and the stern more depressed relatively to the tranquil water level. The column of raised water at the bow becomes higher, producing an accelerated velocity of the stream from bow to stern under level of the rabbet of the keel, and producing, what does not exist with a sufficiently wide channel, a strong current of water flowing from bow to stern on each side of the vessel. A large boat towed at increasing speeds in a canal strikingly illustrates these appearances.

In the displacement of water by the fore body, or by any advancing solid, the direction of the displaced water is always vertical, and consequently above the general level and into the elastic atmosphere, because there is no other place into which it can be delivered. That direction is not only the direction of least resistance, but is the only direction possible, for all the space

below, forward, behind and on either side, is already filled with practically incompressible water. The displaced water commcommences, of course, at the lowest edge of the displacing solid and is limited in breadth by the breadth of that solid. When the displaced water reaches the surface its further movement is caused by gravity alone, which spreads it out over that surface. The best fore body, other things equal, is the one that raises the displaced water to the minimum height above the surface, which means simply the longest fore body and a straight water line. There is no sideways separation of the water by the fore body as by a wedge; there is no sideway motion of any kind communicated by it to the water whose displacement is wholly vertical, and any economic gain expected from fancifully curved water lines, or from any wedge-like action of the fore body, as though the water was a solid, is purely imaginary.

As lifted water, when unrestrained, necessarily flows from the surface supporting it in a direction at right angles to that surface, the water displaced by the fore body will, when it rises above the general level, flow out over that level by gravity in directions at right angles to the sides of the fore body. This movement, which is entirely confined to the surface and has not the least extension beneath it, has caused many errors about "water lines."

The whole theory of "stream lines" and of much other germane matter relating to the dynamics of naval architecture, which have been invented by imaginative mathematicians possessing more facility in the construction of absurd equations than knowledge of the requisite experimental facts which alone can serve as a solid basis for mathematical investigations of physical phenomena, are the merest rubbish, representing nothing as it exists or occurs in nature. They compare to the true laws as the complicated epicycles of Ptolemy compare to the simple system of Copernicus.

The water displaced by the fore body of an advancing vessel has been shown to be necessarily displaced vertically; the stream of water filling the cavity behind the after body also rises vertically because as it comes by vertical pressure from the hori-

zontal plane passing through the rabbet of the keel, where there is the greatest unbalanced pressure, it must necessarily rise at right angles to that plane or vertically. The question may be asked, Why is not the cavity filled by water falling in from its sides rather than rising up from its bottom? The answer is, because the pressure filling the cavity is greater at the bottom than at the sides. That, by virtue of the inertia of the water, time is required to set it in motion, either horizontally or vertically, and as this time is inversely as the pressure, the water has risen from its horizontal plane of greatest unbalanced pressure and filled the cavity before the inertia of the water at the sides has been overcome by the unbalanced pressure there. The continuous generation of the cavity renders the whole action momentary. By reason of this same vertical movement, the water filling the cavity presses upward with a certain velocity over the whole horizontal projection of the cavity, and if the angle of inclination to the horizon of the bottom of the aft body is sufficiently small relatively to speed of vessel, the ascending water columns will press it with force, and to the extent of this force will push the vessel forward. This is an effect of the *vis viva* of the water columns—the product of their weight into the square of their vertical velocity. The weight of the superincumbent vessel is sufficient to prevent it from rising by the *vis viva* of the ascending water, so that the force thus generated acts in the forward direction. The water columns rise with a velocity determined by gravity, and independently of the speed of the vessel, so that for a given speed the less the angle at which the bottom of the aft body rises the more efficiently will the ascending water columns propel it forward. Further, and for the same reason, the greater the speed of the vessel the less should be the angle of rise, so that increased speed requires increased length of aft body, other things equal, as the rise must extend to the surface. That the ascending water should just meet the bottom of the aft body, so as to secure an absence of cavity, is not sufficient for maximum effect; this water must strike that bottom while it has *vis viva*, and the more *vis viva* it has when it meets the bottom the less will be the power required to

propel the vessel, or, in other words, the less will be the resistance of the vessel.

The cavity formed by the advance of the vessel commences really, though not apparently, at the greatest immersed transverse section, and ends at the point where the ascending water reaches the general water level.

The magnitude of the water cavity is masked to the eye by the aft body of the vessel occupying it. The aft body lies in it, and there seems to be no cavity, but if the vessel could be divided at the greatest immersed transverse section, and the aft body lifted out of the water, the cavity would appear in its just dimensions. In order that the cavity should not increase the resistance of the vessel, it must be filled as fast as formed, so as to maintain an equilibrium of water pressure on both sides of the greatest immersed transverse section. With the forward movement of the vessel creating a cavity faster than the ascending water acting under the constant influence of gravity can fill it, an expedient to increase the time of filling the cavity without lessening the speed of the vessel is needed. Such an expedient is the aft body, and it increases the time by the time required for the vessel to move through the length of the aft body; hence the length of the aft body, other things equal, should be directly proportional to the speed of the vessel, in order that the resistance of the vessel be not increased in a higher ratio than that of the square of its speed. In the displacement of water by the fore body of a vessel, time does not enter as an element, and in this respect as in most others, the conditions controlling the forms of the fore and aft bodies, are wholly dissimilar.

If the length of the aft body proportionally to speed of vessel be just what is required to maintain the equilibrium of water pressure at bow and stern, the *vis viva* of the ascending water will be lost propulsively on the vessel; but if the length of aft body proportionally to speed of vessel be greater than the above requirement, the *vis viva* of the ascending water will be, proportionally to this length, expended in pushing the vessel forward. If the whole of the *vis viva* of the ascending water be thus taken out of it, the wake of the vessel will have the same level as that

of the surrounding water. But if the whole of the *vis viva* be not taken out of the ascending water, the wake of the vessel will will be higher than the surrounding water level, the highest point being abaft the stern post, and farther abaft as the *vis viva* remaining in the water is greater.

When the aft body is extremely short, relatively to the speed of the vessel, the ascending water will reach the general level considerably behind the stern post, and will rise by its *vis viva* to a marked height above that general level, appearing like a wave following the vessel. There will be a depression at the stern of the vessel below the general water level, which depression is really the bottom of the after part of the cavity, the aft body, unsupported by the rising columns of water, which arrive too late, sinks as far as the fore body will permit, the vessel changes trim, rises at the bow and descends at the stern, and its resistance becomes correspondingly increased. At the same time the rudder loses its efficiency for want of "solid" water to act upon and the vessel steers wild.

The passage of water beneath the bottom of a vessel, from bow to stern, as the consequence of a greater head at the bow than at the stern, is well demonstrated by the floating timber dock at the Mare Island Navy Yard in California. This dock is rectangular and of sufficient capacity to lift vessels of very large dimensions, vessels drawing 23 feet of water and over. The depth of water required for it is at least 30 feet, the dock remains constantly in the same place, and lies squarely across the current which runs parallel to its sides and bottom; it is in tide water and the current flows in alternate directions according to the tidal conditions. The dock is in very constant use, so that its bottom is ordinarily but a few feet above the bottom of the channel. As a result of the current, the water is heaped above its normal level against the square end of the dock facing it, and is depleted below its normal level at the opposite end. The difference of head between the levels of the water at the bottom of the dock and against the front facing the tide, causes the water beneath the dock, acted upon by the pressure due to the difference of the two levels, to move with a velocity greatly acceler-

ated over the velocity of the tide, and the consequence has been that the scour thus established has deepened the channel several feet below the level of the immediately surrounding ground; has excavated, in fact, a deep cavity or hole just under the dock. There have been times when the dock has been a long while out of use and, of course, floating high out of water, the bottom being but a few feet submerged and having a clear depth of water of 25 feet below it. Under these conditions, the cavity in the ground beneath the dock, scoured out by the locally accelerated current there, is promptly refilled, to be again excavated when the dock is again put in use.

There has been shown that the force which fills the cavity abaft the greatest immersed transverse section of a vessel is the constant force of gravity acting upon a column of water having the height from the level of the rabbet of the keel to the surface of the water heaped up by the fore body, and, as the height of this column is greater than the height of any other column, it acts with preponderating force in filling the cavity, excluding water from the direction of any other pressure. Hence the cavity can not receive water from immediately beneath its sides, forced vertically in by the pressure there, because that pressure is less than the pressure at the front of the fore body.

As the velocity with which the water flows into the cavity is constant, let the speed of the vessel be what it may, evidently, when the speed of the vessel exceeds the speed at which the velocity of inflow just fills the cavity during the time the aft body passes its length, the cavity for this length will no longer be filled—will only be proportionally filled—and the vessel will begin to squat for want of water support beneath the aft body, and the squatting will increase with increased speeds of vessel. Further, squatting will commence with smaller vessels at less speeds than with large ones, simply because, with smaller vessels, the height of the water column producing the flow into the cavity will be less than with large vessels, and the velocity of the inflow will be as the square root of this height. The aft body being shorter there is proportionally less time for filling the cavity during the passage of the length of that body. The above

gives both the cause of the squatting of vessels and the corrollory showing that with vessels of different sizes the squatting will commence at lower and lower speeds as the vessels are smaller and smaller.

In the case of vessels of the same proportions but of different sizes, their heights of water column producing the cavity inflow will be proportional to any of their lineal dimensions; now the velocity of inflow being proportional to the square roots of the heights of the columns, the speeds at which squatting commences will be proportional to the square roots of any dimension of the vessel, and this deduction is confirmed by observation. For example, if a vessel of given dimensions commences to squat at the speed, say, of 10 knots, one of double those dimensions will not commence to squat until 14 knots are attained.

The speed at which squatting commences with any given vessel can be experimentally ascertained by a spirit level adjusted on its deck; the inclination of the bottom of the level with the deck also gives the amount of squatting or its angle. The determination of the speed at which the squatting commences in any vessel, and the amount of squatting due to different increased speeds, are of great importance in the dynamics of naval architecture, but the writer knows of no experiments on this subject except his own.

Simple experiments of this kind will show the exact depth of water, relatively to speed of vessel, at which the influence of the bottom begins to be felt. For example, supposing the vessel to pass at a given speed from deep water into shoaling water, the angle of the spirit level being known, the change of that angle will show that the lessening depth of water has begun to affect the performance of the vessel. Then ascertain the depth by sounding.

If a small fraction of the enormous sums foolishly spent by governments in experimenting at random with the purely military equipment of naval vessels was spent on experiments in naval architecture and in marine engineering, a vastly greater result would be obtained in naval efficiency. Millions upon millions are now spent on vessels, which for want of the neces-

sary direct experimental information, have to be designed largely by rule of thumb and the imagination, because those who control the navies have neither the technical knowledge to properly direct, nor the judgment to sink pride of position and accept the guidance of those who have. The man who does not know, and does not know that he does not know, will not permit the man who does know, and knows that he knows, to direct his presumptuous action.

The squatting can also be ascertained by straight edges placed on the vessel horizontally at a known distance apart, the two edges ranging with the sea horizon or any other very distant mark when the vessel is at rest; then, when in motion at any given speed, if there be squatting, the vertical distance necessary for the farther or forward straight edge to be lowered in order to range the two again with the horizon or distant mark, will show, in conjunction with the horizontal distance apart of the edges, the inclination of the vessel or alteration of its trim. These observations are easy to make in any case, and if a sufficient number be taken under sufficiently varied conditions of speed, depth of water and engine power exerted, the whole problem for that particular vessel can be solved.

When a vessel is propelled by sails alone, with the sails set obliquely to the direction of the keel, it experiences two movements simultaneously, namely, one in the direction of the keel and the other in a direction at right angles to the keel, the latter movement being known as "leeway," but the resistance relatively to its speed in the two directions follow very different ratios, being greatly higher in the direction at right angles to the keel than in the direction of the keel. As a result, the center of gravity of the vessel follows a course between the direction of the keel and the direction at right angles to the keel, and its speed on this course will be greater than its speed in the direction of the keel, and greater than its speed in the direction at right angles to the keel by the difference between the length of the diagonal of a parallelogram and the length of either side, the sides being represented by the speeds in their respective directions. Hence the speed of a vessel obtained by heaving a

"chip log," or from the towing aft of any of the various patent or taffrail logs, will be greater than the truth in proportion to the diagonal of a parellelogram whose sides are represented by the speeds of the vessel in the directions of, and at right angles to, the keel, to the side representing the speed in the direction of the keel.

Now, a given vessel propelled by sails alone set at a given obliquity with the keel, with a given force of wind, state of the sea and angle of the helm with the keel, will make a certain speed in the direction of the keel and a certain speed in the direction at right angles to it. If the force of the wind be increased, all the other above conditions remaining constant, the speed of the vessel in the direction of the keel will increase correspondingly, while its speed in the right-angled direction to the keel will decrease, thus making the "leeway" to diminish not only in its angle, but absolutely. That the speed in the direction at right angles to the keel should decrease with increased force of wind appears paradoxical, and shows there has been some change in conditions other than those above stated. There has. The increased force of the wind has "heeled" or inclined the vessel over farther, and, as a consequence, the bow has "come to the wind" by the more unbalanced pressure of the water on its two sides due to the more "heeling." In other words, the "ardency" of the vessel has been increased, as this tendency to come more and more to the wind by each additional inclination, is termed. That is to say, increased inclination of the vessel changes its course or the direction of its keel, lessening the angle between the latter and the direction of the wind, and thereby decreases the "leeway" absolutely.

If, however, the helm be changed sufficiently to counteract the increased ardency of the vessel and maintain the keel on the same course as before, then the leeway or speed of the vessel in the direction at right angles to the keel will increase with increased force of wind, the obliquity of the sails to the keel not being changed, but the increase in the leeway will be in a very much less proportion than the increase in the direction of the

keel, so that although the speeds in both directions increase, the angle of the leeway decreases.

Why does the resistance of the vessel in the direction at right angles to the keel increase in a higher ratio than in the direction of the keel with increasing force of wind? The answer will be found in the principles already stated. It is because the weather side of the vessel, which, in the right-angled direction to the keel, is the aft body (the central longitudinal plane of the hull from the water line down being in this case the greatest immersed transverse section), is too short relatively to the speed in that direction, and is moreover too improperly shaped to allow the water displaced by the opposite or lee side to fill with sufficient promptness the cavity formed by the leeway. The long aft body of the vessel in the direction of the keel enables considerable increase of speed to be given without raising the resistance in that direction in a much higher ratio than the square of the speed, but the short aft body at right angles to the keel causes the resistance in that direction relatively to speed to rapidly increase in an enormously higher ratio than that of the square.

The greater the ratio of breadth to length in a vessel the greater, other things equal, will be the leeway, and if these dimensions be made the same, in which case the water plane would be approximately a circle, the vessel, except for the effect of what modeling can be given to it below the water plane and of the keel, would make as much leeway as headway with the sails set at the angle of 45 degrees with the course. The only reason why any sailing vessel makes more headway than leeway with the sails thus set, is its difference of resistance in the direction of the keel and in the direction at right angles to the keel. In the sailing vessels of navies, previous to the introduction of steam enginery, having lengths of only from $3\frac{1}{2}$ to 4 times the breadth, the leeway was enormous, and great improvement in the lessening of it was made by simply increasing the ratio of the length to the breadth, this, however, being done at the expense of the manœuvering power.

In what are known as the *Popoffskas*, or bowl-shaped ironclads, although propelled solely by screws, the steering qualities are

from this cause so poor as to render them nearly unmanageable by the rudder. When these vessels have headway in the direction of the axes of their screws, and an attempt is made to change the course by putting the helm over, the reaction of the water on the rudder simply revolves the vessel upon its center of gravity as a pivot, while that center retains its movement in the original direction until the *vis viva* of the vessel in that direction is extinguished by being transferred to the water, after which the vessel starts in the intended new direction, but not till then. The vessel, by the action of its rudder, turns promptly enough on its center of gravity, but owing to its want of sideway resistance is a long time in losing its movement in the original direction. These phenomena are, of course, the same in degree in all vessels, but become less and less marked in proportion as the sideway resistance increases relatively to the *vis viva* of the vessel.

The immersed portion of the *Popoffskas* has a turbot-like form, by virtue of which they present to the water when moving ahead an inclined plane, up which it can be forced with great ease; as a consequence, when these vessels have any considerable speed, the weight of water thus driven upon the top of their bows is sufficient to much depress them, with a corresponding rising of the sterns, so that this form of hull seems to have "a damnable alacrity" in diving, which is only checked by the fact that the tilting, by lifting the aft body, increases its moment and thus establishes an equilibrium.

The same difficulty as regards steering has been found in some British ironclads of great beam proportionally to length, and with fore bodies and aft bodies made very full to furnish as great a displacement as practicable on the lineal dimensions, while the keel was entirely omitted in order to reduce the draught of water. The cause was precisely the same as just described, and the effect was so marked that the sideway resistance of the vessels had to be increased by an extension of vertical surface abaft the hull in its longitudinal central plane. A similar extension was not made forward of the hull, where it would have been equally efficient, because of its obvious inconvenience there. It

was not practicable to give enough surface of this kind to wholly overcome the defective steering.

The sailing vessels exclusively forming navies previous to the introduction of steam power, and having lengths of from $3\frac{1}{2}$ to 4 times their breadth, had no difficulty in steering; in fact, they steered extremely well, because, although made very full at the water line to give stiffness under sail, they were modeled exquisitely fine below it, exposing considerable surface nearly vertical. They were fitted, too, with keels of great depth, extending the entire length of the vessel and containing much vertical surface. The necessary sideway resistance was thus obtained, but the badly-steering British ironclads above cited had no keels, and had full models below as well as at the water line; the omission of the keel ruined their steering qualities; had they been fitted with keels of moderate depth they would have steered well enough, but the addition of keels was out of the question on account of their already too great draught of water. The vertical surface added to the vessel abaft the stern was a substitute for a keel, but was less efficient per unit of surface than a keel would have been, because less immersed and not being equally distributed on opposite sides of the center of gravity of the vessel.

The leeway of sailing vessels increases with their "heeling" or inclination by the action of the wind or their sails, other things equal, because the inclined vessel has less sideway resistance than the erect vessel. Hence, lengthening the vessel above the water line, or projecting the bow and stern beyond their repective stem and stern post below water, is very advantageous to speed when sailing on the wind, and especially when the wind is strong enough to considerably heel the vessel, because the additional immersion due to the heeling increases the sideway resistance and correspondingly lessens the leeway; also, by increasing the stiffness of the vessel, it enables more sail surface to be carried at the same inclination; the additional displacement gained by the greater immersion more than compensates the additional weight of the projecting bow and stern, so that the draught of water is lessened. Of course, these advantages

disappear with winds either too light to heel the vessel, or not in the proper direction for that purpose, but even with an aft wind, if it be a very strong one, the projecting bow above water is advantageous, as it prevents the vessel from burying forwards by the leverage of the pressure of the sails. This expedient of projecting the bow and stern well over the water surface gives to a vessel of a certain nominal length on the water line, the advantages of a much longer vessel on that line, under the conditions described.

The foregoing investigations demonstrate the fundamental laws regulating the movement of ship-formed bodies in water, and illustrate the manner in which the water reacts on them. These laws must be indisputably ascertained by observation and by experiment before dynamics can be applied to naval architecture. As far as the statics of naval architecture are concerned the science can be considered as complete, but this is far from being the case with the dynamics of naval architecture, the received ideas of which are, in the writer's opinion, based on wholly erroneous assumptions made in direct opposition to the most obvious phenomena in nature, impossible in fact and inconceivable by reason.

The principles announced by the writer are, among others, in brief: that the displacement of water by the fore body of an advancing vessel is wholly vertical and not at all horizontal or sideways, the displaced water being delivered into the elastic atmosphere and above the level of the surrounding water; that the continuous advance of the vessel maintains a constant elevation of the displaced water at the front of the fore body above the surrounding water level, producing a permanently greater pressure there than is to be found in any other portion of the indefinite mass of water in which the vessel moves; that the height to which the displaced water is lifted against the front of the fore body is proportional, other things equal, to the length of the inclined side of the fore body; that the displaced water so lifted flows outward by gravity over the surface of the surrounding water and in directions at right angles to the inclined side of the fore body; that this flowing outwards is purely a surface

phenomenon, and does not in the least affect the water lying below the general surrounding level; that the work of this displacement consists in lifting the displaced water above the general water level, and is measured in quantity by the mass of water lifted in a given time and the height above the general water level to which it is lifted; that the work done by the fore body in displacing water is entirely independent of any effect produced by the aft body; that if the back of the fore body be not supported by water in such manner as to maintain a static equilibrium on the opposite sides of the greatest immersed transverse section of the vessel, there must be added to the above work of displacement the work due to overcoming the difference of pressure on these opposite sides; that as no such equilibrium of static pressure can ever exist, the work done by the fore body is always greater than the work of displacement; that this additional work done by the fore body is greater, other things equal, as the length of the inclined side of the fore body is less; that to the above two kinds of work done by the fore body must be added a third, namely, overcoming the resistance of its wetted surface, which work is proportional to the surface and to the cube of the velocity of the water molecules passing along the inclined side of the body; this work is so large a fraction of the total work done by the fore body as to modify enormously the dynamic value of length of body abstractly considered, or considered solely in relation to its economic displacement of water; lengthening the fore body, other things equal, diminishes the work of displacement but increases the work of the surface resistance, so that a length is soon reached, depending on absolute speed, beyond which any additional length is economically injurious, and the greater the speed of the vessel the longer will be the body before the length of maximum economy is passed; the length for maximum economy at one speed is not the proper length at another speed, but there is, with all vessels, a considerable interval of speed during which the losses and gains are so nearly balanced that the difference is insignificant; that the advance of the vessel leaves in the water a cavity extending aft from the greatest immersed transverse section a certain distance depending on cir-

cumstances; that this cavity is filled and wholly filled by water flowing into it vertically from the bottom thereof; that the quantity of water which flows into the cavity in a given time is exactly equal to the quantity displaced in the same time by the fore body, but the length of the cavity is proportional to the speed of the vessel; that the cross section of the cavity at the greatest immersed transverse section of the vessel has the form and dimensions of that section; that the water filling this cavity comes in a horizontal stream from the stem of the vessel to its greatest immersed transverse section, the upper surface of the stream being the horizontal plane of the rabbet of the keel, but no portion of the stream is in contact with the fore body.

The breadth of the stream varies from nearly nothing at the stem to the breadth of the greatest immersed transverse section at that section. After the stream passes the greatest immersed transverse section, where it has its maximum breadth and depth, it rises vertically into and fills the cavity. A quantity of water equal in a given time to the displacement of the vessel in the same time, has to be forced under the horizontal projection of the greatest immersed transverse section and in contact with it, and the pressure to produce this forcing is the pressure due to difference of the level of the water in contact with the front of the fore body and the level of the water in the bottom of the cavity. The direction of the stream is, of course, the straight line between these maximum and minimum pressures; that the water rising vertically into the cavity has a certain amount of *vis viva*, and if the water strike the overhanging inclined surfaces of the aft body, this *vis viva* will be expended upon them, and will correspondingly produce a forward pressure on the aft body, assisting, to that extent, the propulsion of the vessel; the less the inclination of the overhanging surfaces, evidently the greater will be the *vis viva* of the water with which they will be struck. If the angle of inclination of the overhanging surfaces, and the speed of the vessel, be such that the ascending water barely meets the surfaces, then there will be no *vis viva* expended upon them, but the vessel will just maintain its trim. In this case the *vis viva* will carry the ascending water above the level of the

surrounding water and cause a wave or water elevation abaft the stern and close to the stern post. If the speed of the vessel be now increased, all other things remaining the same, the rising water will no longer reach the overhanging surfaces in time, and for want of this support the stern will begin to "squat," correspondingly lifting the bow, and the wave or water elevation will appear further behind the stern post. If the speed of the vessel be more and more increased, these phenomena will become more and more marked, the stern will continue to squat, the bow to rise, and the wave or water elevation abaft the stern will become farther and farther from the stern post. If the speed be increased to an extreme proportionally to the dimensions of the vessel, the stern will sink to such an extent that the surrounding water level will be above the taffrail. The aft body has to sink until it meets with sufficient support from the rising water, in conjunction with the sustaining power of the fore body, to prevent farther descent; as long as the speed of the vessel increases, the stern will continue to squat except in so far as the fore body can hold it up, but the inclination of the vessel which results from this squatting increases its resistance by increasing its greatest immersed transverse section, and by lessening the height of the water column on the aft side of that section; if the vessel be screw propelled, the propelling efficiency of the screw is enormously lessened by the same causes, its slip being greatly increased, so that a limit to the speed is in this manner made by the speed itself; the inclination of the vessel produced by the squatting of its stern, makes it rise bodily in the water at a less speed than it otherwise would; the whole subject is excessively complicated from the fact that the slightest change in one of the conditions changes all the others; the attempt to apply mathematics either to express the problem or to numerically determine any of its quantities, is simply preposterous; if, even in the comparatively elementary cases of astronomy, the results can only be obtained by successive approximations, dealing with but two or three factors at a time, what can be hoped in the case of physical phenomena where the factors are so numerous, their values so undetermined, and their combinations

almost endless? That the ship-formed fore body is an expedient to lessen the height to which the displaced water has to be raised above the general water level, the longer the fore body the less the height; that the ship-formed aft body is an expedient to increase the time available for filling the cavity, the force (gravity) filling the cavity being constant, the time required for the filling will be directly proportional to the speed of the vessel; that the resistance due to the wetted surface of the fore body is proportional to that surface and to the cube of the velocity with which the water passes over it, the direction of the water motion being vertical—not horizontal; that the resistance due to the wetted surface of the aft body is proportional to that surface and to the cube of the velocity with which the inclined surfaces pass over the ascending water columns, the general movement being horizontal—not vertical; in the case of the fore body, the water moves over the surfaces, while in that of the aft body the surfaces move over the water; that as the resistances of the wetted surfaces form so large a portion of the total resistances of vessels, and affect the problem in so diametrically opposite a direction to that of the resistances due to form alone, the dynamics of naval architecture is purely a practical art—wholly tentative—and independent of abstract science; this does not apply, of course, to the statics of naval architecture; that squatting occurs in all vessels whenever their speed passes a certain limit; that after this speed is passed the resistance of the vessel, which previously was in the ratio of the square of the speed, becomes in a higher ratio, the ratio increasing as the speed increases, provided the vessel does not lift bodily in the water, should it do so, then, from that moment, the ratio changes again and may decrease, or otherwise change according to circumstances; that the larger the vessel, its proportions being the same, the greater will be the speed before squatting commences; that the longer vessel, other things being equal, will require a higher speed before squatting than a shorter one.

When a vessel passes from deep water into shoal water, the same phenomena appear as when it is driven in deep water at a speed higher than its squatting speed. As the water continues

to shoal, so do the phenomena continue to correspond to increasing speeds in deep water above the squatting speed, and the cause in both cases is the same, namely, the too slow velocity with which the water filling the cavity passes horizontally beneath the greatest immersed transverse section. But there is this difference, that in the case of the vessel in shoal water there is an additional cause producing the too slow velocity, so that the velocity with which the water passes to the cavity at a given speed of vessel in deep water, becomes a much less velocity at the same speed of vessel in shoal water. This slower velocity with which the cavity is filled in shoal water than in deep water, the velocity of the vessel being constant, is due to the resistance of the ground, which, acting on the under side of the stream flowing from the commencement to the end of the cavity, retards its flow correspondingly. In deep water the under side of this stream flowed over other water offering comparatively little resistance, but in shoal water it flowed over rough and uneven ground, offering a very great resistance, and, in extreme shoalness, there was not enough area between the wetted perimeter of the greatest immersed transverse section and the ground to pass the water under constant pressure, consequently the cavity was not filled in time, the trim of the vessel changed enormously by the resulting squatting of the stern, the ascending water did not reach the general water level until a long distance abaft the stern, and then reached it with almost the entire *vis viva*, which carried the ascending water high above that level, producing the appearance of a wave following the vessel, and having between it and the stern a large hollow. The bow, lifted higher above the general water level, carried before it a higher wave than before, as all the water of displacement could not be forced in time beneath the wetted perimeter of the greatest immersed transverse section and the ground, the area of that section was increased, the resistance of the hull was greatly increased, the fraction of the power developed by the engine applied by the screw propulsively was lessened, and the speed of the vessel was by each and all of these effects decreased. The primary cause of the whole was the fact that the lower surface of the horizontal stream flowing from the

commencement to the end of the cavity, was in contact with the ground. This is the explanation of the enormous influence exercised upon the speed of a vessel by very shoal water. The shoaler the water, the greater will be that influence in diminishing the speed, and some of this influence will be sensibly felt in even comparatively deep water, owing to the cohesion of water whereby a stream communicates some of its motion to adjacent quiescent water.

In the movement of ship-formed solids through water, the displacement and replacement of the latter are always in vertical directions—never horizontally. There is no sideways separation of the water by the fore body as of a solid by a wedge, nor is there any sideways flowing in around and behind the aft body. Were the cavity thus filled, shoal water could not produce the slightest effect upon the vessel's resistance or its speed, nor would any of the phenomena attending the passage of vessels through water be affected by shoalness as long as the vessel did not touch the bottom.

All the phenomena of vessels of different dimensions passing through water of different depths, and at different speeds, are completely explained by the movements of the water described by the writer for the first time in this paper; and these phenomena cannot be explained in any other manner.

# THE CHASE OF THE *ITATA*.

By Passed Assistant Engineer Ira N. Hollis, U. S. Navy.

The following record of the *Charleston's* cruise during May and June, 1891, in chase of the *Itata*, is published after the lapse of a year, through lack of opportunity for earlier preparation. The main facts are still of interest, notwithstanding their remoteness, as the performance is that of a modern cruiser on the duty she was built for in war times. Particular attention is paid to the machinery and boilers, in order to note every casualty that might have crippled the ship in time of action. A brief summary of the ship's log from day to day is also given. No mention is made of those things which ran smoothly and required no attention. The sea and weather, the number of boilers in use, the kind of draft employed, will not be referred to unless there is a change of conditions.

The *Charleston* left Mare Island on Thursday, May 7, 1891, with orders to test the two eight-inch guns in position, and then await orders at San Francisco. She had had a great deal of steaming since leaving the yard twelve months before, but the engines and auxiliaries were in excellent condition. New and additional supports had been fitted under the smoke pipe, but no other repairs had been found necessary. It is interesting to note that the officers and crew had no suspicion that they were bound on a foreign cruise, and no sea stores had been laid in by the messes. The morning papers contained notices of the escape of the *Itata* from the marshal's custody in San Diego. The *Robert and Minnie* had sailed from San Pedro on the same day, and it was conjectured that the two vessels had met near one of the islands off Santa Barbara, where the cargo of arms had been transferred. (This subsequently turned out to be correct.) The *Charleston* lay off San Francisco Thursday night and all day Friday with sailing orders for eight o'clock that night, the in-

tention being to go out at four in the morning of Saturday and get through with target practice before the fog. Three visitors came off in the last boat to see the firing; also a telegram in cipher for the captain. This telegram was not fully made out until after all hands had gone to bed. The strangers were called at half-past three, Saturday morning, and put on shore, and the ship went to sea with orders to proceed south in chase of the *Itata*. The officers' messes were poorly provided with fresh provisions, and it was with some discouragement that we found ourselves headed out to sea on an indefinite cruise without even potatoes. The orders were not known outside of the cabin until we reached Iquique, four weeks later.

*Saturday, May 9, 1891.*—Steamed down the coast of California at a speed of 11 to 13 knots with a smooth sea and light wind. Steam on four boilers, using anthracite coal, which necessitated running the forward blowers at 200 revolutions and about ¼ inch air pressure in the fire room. Another boiler, added late in the afternoon, did away with the blowers. Slowed down to 4 or 5 knots at nightfall on account of light fog.

*May 10.*—Increased the speed at 4 A. M., to 12 to 13 knots with five boilers in use and natural draft. Steered the ship by signal to the main engines for half an hour, to repair stranded wire rope of the hydraulic control valve. Slowed down, and spoke two vessels during the day, but got no news of the *Itata*. Passed through the Islands of the Santa Barbara Channel and anchored off San Pedro after dark. Communicated with the *Omaha* and the shore and found the *Robert and Minnie* in port. The *Itata* had left for parts unknown three days before with a cargo of arms on board, also with a quantity of provisions and live stock purchased in San Diego. Lay under banked fires all night.

*May 11.*—Left San Pedro at 5 A. M., and steamed south under five boilers with natural draft, making from 12 to 13 knots. Sighted a steamer in shore towards evening. Upon changing course, found her a small coaster.

*May 12.*—Steaming south along the coast of Lower California. Increased the speed to 13 to 14 knots during the forenoon

by starting the forward blowers, with an air pressure of ⅜ inch in the fire room. Coal mixed and very bad. Plugged a leaky tube in the starboard forward boiler with a patent plug, but leak continued so bad that boiler was taken off, and fires started in the remaining after boiler during the first dog watch. Started after blowers at noon with air pressure of ⅜ inch in fire room.

*May 13.*—Steaming down the coast of Lower California under five boilers, making from 13.5 to 14.1 knots.

Blowers running with about ⅜-inch pressure in the fire rooms. Corked up the speaking tubes from fire rooms to forward engine room, and put U tubes made from gauge glasses through the corks, with colored liquid in the tubes to determine air pressure in the fire rooms, and thus check the water tenders. Cleaned out forward boiler during the day and put cast iron washers, connected by a wrought-iron rod, over the ends of the leaky tube. Steered the ship with main engines from 6 to 7 P. M.,repairing stranded tiller rope. Stopped port after blower one hour during first watch, to tighten up on eccentric bolts. Sighted a brig-rigged steamer standing to northward at daybreak.

*May 14.*—Steaming across the Gulf of California under five boilers, making from 13 to 14 knots. Blowers running with ½-inch to ⅝-inch air pressure in the fire rooms. Stopped port after blower from 7 A. M., to 11.15 A. M., for repairs. The eccentric wrist-pin had dropped out and the adjusting bolt of the crank-pin brasses had broken. Stopped starboard after blower from 1.30 to 2.30 P. M. to set up on brasses. Stopped it again at 6.30 and found eccentric wrist pin out and eccentric strap broken. Plugged a leaky tube in starboard after boiler. During the day the ship was steered by hand, while reeving off new wire rope on the port side to the hydraulic control valve of the steering gear. The old rope had corroded through in places and stranded.

*May 15.*—Steaming along the Mexican coast under five boilers, making from 11 to 14 knots. Started fires in the sixth boiler and connected it at 8.20 P. M., thus giving the ship full power after speaking the *Colima*. Running three blowers with ⅝-inch to ¾-inch air pressure. Starboard after boiler leaking badly and salt feed much in use. Fire rooms and engine rooms

oppressively hot and men suffering. Stopped the port after blower from 9 A. M. to 2.45 P. M. to repair; one eccentric bolt broken and one disappeared. Stopped it again from 7 to 10 P. M. with thread on the end of eccentric rod stripped. The starboard thrust rings working warm for one watch and water in use. Steered by hand one hour and forty minutes, while repairing stranded wheel rope. Slowed down for fifteen minutes during the afternoon to speak the *Colima*. Stated she had passed a Chilian vessel bound into (or near) Acapulco during the morning. The message was ambiguous.

*May 16*.—Steaming along the Mexican coast under all boilers, making 14 knots. Running three blowers with air pressure ½ inch. The two forward blowers were stopped one-half hour during the midwatch to set up on eccentric straps. The starboard after boiler leaking badly and salt feed in almost constant use. At 3.30 A. M. a light was sighted on the port bow, which proved to be a steamer; later, two lights discovered, one above the other, but no running lights. Headed towards the lights, when the steamer threw a strong search light on us. Extinguished running and other lights and sounded alarm for general quarters. Loaded port battery with shell. Ran slow until daylight, after which steamed into harbor of Acapulco at 6.30 A. M. The ship was turned around ready to go out, without anchoring, while sending a boat on shore for the U. S. consul.

The search light above mentioned was the first intimation of the presence of a man-of-war near Acapulco. From the position of the light, we conjectured her to be the *Esmeralda*. Daylight disclosed no other ship in sight, however. One hour after the entry of the *Charleston*, the consul came on board, with information that the *Esmeralda*, after remaining in port several days, had been lying outside three days, and that at dusk, the evening before, the smoke of a second steamer had been sighted from the signal station. The *Esmeralda* entered the harbor at 8 A. M., upon which we anchored and began taking in coal. It may be interesting to note that our conjecture that the *Itata* had met the *Esmeralda* just after dark of the night before, had been warned to go south immediately, as there was no time to transfer

stores, and had left some hours before our arrival, turned out to be correct. She steamed directly south on a meridian for about one hundred and fifty miles, where she lay to fifty hours repairing the thrust which had given out. We subsequently passed her well to the eastward.

During the day the fires of the starboard after boiler were hauled and the safety valve raised to hasten repairs on the tubes; the fires in the other after boilers were allowed to die out. Steam was well kept up in the forward boilers and full watches on ready to leave at short notice. The tubes and furnaces were all cleaned and everything made ready for another long voyage, Coaling was continued by natives from shore.

The following facts have been noted in connection with this voyage, on account of their importance in the design of a new ship and bearing on long and continued steaming:

The coal used was a mixture of anthracite containing a large percentage of slack and bituminous slack left over in the bunkers. It was entirely unsuited for use in the boilers which contained furnaces and combustion chambers designed especially for Welsh coal. Experience had shown during the first year of the cruise that anthracite required one more boiler for ten knots than bituminous, and the blowers had to be run constantly to get twelve knots with the former under five boilers. The defects in the design of the blowers were well developed. Their location immediately over the wing furnaces and nearer the bunker doors made it impossible to keep grit and ashes from the bearings and pins. Notwithstanding all possible care, the brasses worked loose and warm after two or three watches. The eccentric straps were entirely too light and the fastenings generally bad. On the voyage to Callao and returning from Iquique, wrought-iron straps were made on board, with brass liners riveted in for wearing surfaces, to replace three broken straps. Constant watchfulness was required to keep down the speed of the blowers. The water tenders and firemen were encouraged to laziness by the possession of ready means of regulating the steam pressure. Orders had invariably to be given to reduce the air pressure while cleaning fires, as the tendency among

the men was to keep up steam by speeding the blowers, in spite of the injurious effect upon the tube ends of the boiler whose doors were open. The engineer on watch could not be in the fire rooms very much. He had the main engines and auxiliaries, the ventilating fans, the hydraulic steering gear, distilling, and the handling of coal in the upper bunkers, to look after, in addition to the boilers. Generally, a sudden and considerable change in the speed of the blowers could be detected in the engine room by the sharper whistling of the speaking tubes; but the gauge put in on the thirteenth suggests a much better method. It answered admirably until some fireman with good lung power blew cork, glass and liquid out of the tube. The closed fire rooms were comfortable except along the Mexican coast where the weather was oppressive, and the men preferred them to natural draft. The use of blowers with moderate air pressure did not seem to have a specially injurious effect upon the tubes. An examination always showed leaks around the tube ends with, generally, a small amount of salt in the combustion chambers, after natural as well as forced draft. Most leaks in the boilers were due to pitting of tubes, which would go suddenly and cause serious loss of water. These pits, or holes, occurred indifferently throughout the tubes and were probably due to defects of manufacture. The watertight bulkhead between the fire rooms was so close to the tube ends that long plugs had to be made in two pieces, and no very satisfactory method of plugging could be devised. Plain wooden plugs connected by common iron piping were tried, also short plugs intended to fill only two or three feet of the tube, but with little improvement of the leaks.

The time required to get up steam on emergency was well tested. From cold water, with anthracite coal and good draft already formed in the stack, the boilers could be connected up with full steam pressure in two hours. The hydrokineters were found very useful in heating the water to boiling point and keeping additional boilers ready for use. In this way, boilers could be connected up in half an hour without injury to the parts.

During the entire run, at speeds varying from thirty to ninety revolutions, the main engines gave no trouble whatever. The circulators ran with little attention. The after air pump stopped several times while running the main engines slow, probably on account of the small opening of throttle and sudden access of water due to rolling of ship. In default of a governor, the air pumps required constant watching. Their crank pins heated from time to time, especially those which caught the dirt from the hatches. Some months later the brasses were lined with white metal and the heating completely cured. After a year's experience in handling coal, the engineer's force was barely sufficient in numbers to keep up the coal supply, although the expenditure never exceeded seventy-two tons per day. The main difficulty lay in getting coal from the upper to the lower bunkers.

The following tabulated statement of distances and coal consumption may be found useful in calculating the ship's endurance on a coal bunker capacity of 760 tons, bearing in mind that anthracite of poor quality was used:

| Date. | Hours run. | Distance. | Coal expended. |
|---|---|---|---|
| May 11 | 18 hrs. 30 m. | 213 knots. | 40 tons. |
| " 12 | 24 " 00 " | 309 " | 63 " |
| " 13 | 23 " 48 " | 325 " | 65 " |
| " 14 | 23 " 50 " | 322 " | 62 " |
| " 15 | 23 " 46 " | 305 " | 72 " |
| " 16 | 6 " 30 " | 78 " | 22 " |
| | 120 hrs. 24 m. | 1552 knots. | 324 tons. |

The above includes coal for distilling, ventilating, electric lighting and galley.

Owing to lack of artificial ventilation, the engine rooms were oppressive south of Cape San Lucas; in fact, they were almost unendurable.

*May 17.*—Cleaning boilers and receiving coal. During the day it became evident that the Mexican coal stowers would not

work, and the coaling was accordingly stopped at 6 P. M., having received 350 tons of Cardiff coal; 40 tons were hoisted on deck in bags. The repairs to the eccentric strap of the blower were continued, the crank pins and wrist pins of the main engines adjusted slightly, and two tubes in a leaky boiler plugged with cast-iron washers. Started fires in one after boiler and connected it with forward boilers. Steamed out of the harbor at 7 P. M. and headed northerly for two hours with all lights extinguished; after that headed for Callao, making about ten knots with four boilers and natural draft.

*May 18.*—Steam on four boilers with natural draft. Revolutions limited to 65 during the forenoon; after that to 60, giving 11.2 and 10.5 knots. Sharp lookout kept for smoke on the horizon.

*May 19.*—Speed from 10 to 12 knots. During the day changed the fires in two boilers on account of high saturation. The fire pump broke down during the forenoon; found the water piston rod corroded off in the nut. The starboard air pump was stopped fifteen minutes to set up on wrist-pin brasses. Engine rooms oppressively warm.

*May 20.*—Speed about 11 knots. Plug in starboard after boiler leaking. Ran sea water into two cold boilers, after having pumped them down.

*May 21.*—Speed 11 knots. Ran one after blower for a short time at intervals during the day to burn the soot out of tubes and improve the draft. Tube leaking in port after boiler. Attempted to plug it with wooden plugs, but failed to stop the flow of water. Joint blew out in feed check of forward boiler. The escape of steam and water was stopped by driving in pine wedges. Stopped starboard main engine twenty minutes to replace wiper of air-pump crank pin.

*May 22.*—Speed 11 knots. Running blowers at intervals. Coal a mixture of anthracite and bituminous. Two after boilers leaking and salt feed in constant use. Steam taken off the port after boiler and the port forward boiler connected up during the afternoon.

*May 24.*—Speed, 11 knots. Plugged tubes of port after boiler

with cast-iron washers. Salt feed in use for leak in after boiler. During the day, the speed was maintained without effort.

*May 25*.—Speed, 10.5 knots. Coal, a mixture of bituminous and anthracite slack. Blowers run at intervals; continuously after 6 P. M. Salt feed used frequently.

*May 26*.—Steaming with four boilers and all blowers running slow. Speed, 11 to 12 knots. Port after blower stopped at 3.30 P. M., with broken eccentric strap. Steamed into harbor of Callao at 6.30 P. M., with starboard air pump hammering very heavily in the after steam cylinder. At 5 P. M., two double bottoms were filled to increase the stability while crossing a heavy ground swell. The fires were banked after anchoring.

An examination of the air pump disclosed the fact that the end of the packing ring had broken off and dropped into the bottom of the cylinder where it was just sufficient to fill the clearance. This ring was made of forged steel, which had worn very irregularly and had been reduced in thickness one-half at the joint. This joint was peculiarly fragile, as it had been made by filing the ring out and riveting a short tongue to one end, as shown in the sketch:

One of the feed-pump rods broke before entering Callao.

During the run, the sea was smooth and the weather good. A constant lookout was kept for the smoke of a steamer during the day, and lights at night. The revolutions were generally fixed to give about 11 knots.

There was general disappointment over the lack of news of the *Itata* in Callao.

A tabulated statement is given below of the coal consumption and speed. The coal used was a bad mixture of anthracite and bituminous, and the expenditure includes that for all purposes:

| Date. | Hours. | Knots. | Coal. |
|---|---|---|---|
| May 17 | 4½ hours. | 55 knots. | 14 tons. |
| " 18 | 24 " | 256 " | 54 " |
| " 19 | 24 " | 255 " | 52 " |
| " 20 | 24 " | 261 " | 54 " |
| " 21 | 24 " | 260 " | 57 " |
| " 22 | 24 " | 262 " | 58 " |
| " 23 | 24 " | 264 " | 57 " |
| " 24 | 24 " | 259 " | 66 " |
| " 25 | 24 " | 256 " | 66 " |
| " 26 | 18½ " | 207 " | 54 " |
| | 215 hours. | 2,335 knots. | 532 tons. |

The impossibility of living in the engine rooms with the battle doors closed had been so apparent before Acapulco that the blacksmith was kept constantly at work making braces from spare grate bars to support the middle doors at an angle of thirty degrees. These doors were replaced by gratings after the return to Mare Island.

*May 27.*—Fires allowed to die out in the starboard after boiler to plug tubes; fires banked in three boilers. The day was employed in cleaning tubes, repairing blowers and feed pumps, plugging tubes of two boilers and getting engines ready for sea. Receiving Cardiff coal from noon to midnight, stowed by men from shore.

*May 28.*—Fires banked in three boilers. Changed fires to after boilers, leaving forward fire-room free. Examined nuts and brasses of all blowers. Other repairs and coaling continued. Steamed out of harbor at 8 P. M. and headed south, making 7 to 9 knots.

*May 29.*—Fires in three after boilers with natural draft. Speed 10 knots, with moderate head sea and wind. Using a good quality of Cardiff coal, the expediture for all purposes being 34 tons.

[NOTE.—This was the only day of the entire voyage when good unmixed coal was used and a steady speed was maintained with purely natural draft.] Piston valves of L.P. engine chattering. Repairs on blowers continued.

*May 30.*—Fires in three after boilers with natural draft. Speed, 10.4 knots to 10 A. M., then variable. During the morning watch the smoke of a steamer was sighted well to the westward proceeding south. At 8 A. M. she suddenly shifted her course to north. The *Charleston* was headed in her direction and soon brought the masts and hull in sight. She corresponded well with the description of the *Itata* obtained in Callao. Gained very slowly on her from 8 to 10 A. M. At this time, the forward boilers were entirely empty and the grates bare. Ran water into the boilers, primed furnaces and started fires in two boilers. Connected them at noon, having required 2 hours 15 minutes for one and 2 hours 45 minutes for the other from empty boilers. The hydrokineters were freely used and the fires spread as the coal caught. Added the sixth boiler at 2 P. M., having required 1 hour 15 minutes to get steam, starting with water quite warm. One after blower was started at 9 A. M. (the other being under repairs), the two forward blowers at 12.30 P. M. At 1.10 the port forward blower stopped with broken eccentric strap. Averaging from 13.5 to 14 knots from noon to 3 P. M. to overhaul the steamer which turned out to be the *Karnah*, a German tramp. The ship was accordingly headed south, the blowers stopped and the fires forward allowed to die out. The average speed for the twenty-four hours was 11¼ knots on a consumption of 47 tons of coal.

*May 31.*—Fires in three boilers. Speed variable. Cleaning forward boilers and completing repairs to blowers. Several ships were sighted and examined carefully with the glass. No *Itata*. Average speed, 9 knots. Coal, 28 tons.

*June 1.*—Steaming into harbor of Arica. Steering engine behaving badly on account of continual racing of accumulator pumps. Subsequent examination showed the suction and delivery valve seats and faces much worn and cut. Came to anchor at 10 A. M. near the *Pensacola*. No news of the *Itata*. Banked fires. Cleaning boilers and working on repairs to blowers and accumulator.

*June 2.*—Banked fires in three after boilers; tubes of two of them leaking slightly. Examined L.P. cylinders and found them

in fine condition. Ground in water valves of hydraulic pump. Repairing and getting ready for sea.

*June 3.*—Examined H.P. cylinders and found surfaces in good condition. Cleaning and repairing. Left the harbor at 5.45 P. M. for Pisagua, under three after boilers. Broke bolt of universal joint of main stop valve in hydraulic room and had to open valve with pipe wrench. Speed, 4 to 5 knots.

*June 4.*—Steaming with three after boilers. Passed close to the harbor of Pisagua and found no *Itata*. Came to anchor in Iquique harbor at 11.40 A. M. and found the *Itata* anchored astern of and between the *Baltimore* and *San Francisco*. She had arrived a few hours before, and had been surrendered to the American fleet.

*June 5–12.*—During the stay in Iquique the machinery was examined and cleaned ready for sea. The pins were all stripped and brasses adjusted, a number of boiler tubes expanded or plugged, and the blower repairs completed.

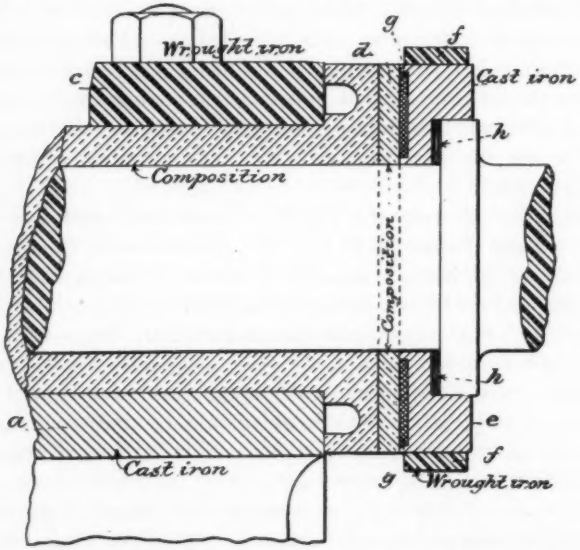
*June 13–July 4.*—*Charleston* returning to San Diego with the *Itata*. Three boilers in use, speed varying from 8 to 9 knots, and machinery working well. Nothing gave trouble, and the cruise was uneventful. The total amount of coal used for all purposes was 626 tons, an average of about 30 tons a day, and the distance made was 4 308 knots.

*June 8–12.*—A force of men was placed on board of the *Itata* to make necessary repairs for a cruise. The work began on the morning of the eighth and was completed at noon of the twelfth. The engines were turned over under steam and worked satisfactorily. Both ships left Iquique for San Diego on the evening of the thirteenth.

A short history of the *Itata* and the repairs made by our men is appended.

The *Itata* was taken by the insurgents in the early part of the war for use as a transport. She was in constant service up to the time of her departure for San Diego, a period of three months, and there was no time allowed to overhaul and adjust machinery or clean boilers. Her engines, fully twenty years old, are of the usual merchant-ship type, compound vertical; cylinders,

45 inches and 88 inches × 45 inches, with condenser running fore and aft, and supporting one side of the cylinders; air and circulating pumps actuated by beams from the crossheads. The parts are all very heavy, with large bearings, pins and brasses. The only peculiarity is in the construction of the thrust bearing, which is shown in the accompanying sketch. The thrust is




taken by a wearing ring, *d*, secured to the after main-bearing brasses, which are cast with a large disc on the after end. This disc fits in against the engine bed plate and the cap of the bearing. The thrust-ring *e* is made in two parts, of cast iron, lined with white metal, *g*. It is held in place by a wrought-iron ring, *f*, slightly tapered on the inner surface to force the two halves together. Liners *h* are placed between the thrust ring and a collar forged on the shaft.

There are four single-end boilers of the ordinary return tubular type with three furnaces in each. These boilers are new and without lagging. It had been left off to calk all leaky seams and rivets in actual service.

The ship started north from Arica in April, 1891, with bottom foul and engines in bad adjustment. One of the boilers was leaking badly in the combustion chamber, but no time was allowed for repairs. She was accompanied to San Lucas by the *Esmeralda*, whence she proceeded alone to San Diego. The voyage was made at the rate of eight or nine knots, stopping repeatedly to send provisions to the *Esmeralda*, and once, for two days at the Galapagos Islands, to send coal. Other stops were made to remove broken parts of the machinery, notably the H.P. cut-off valve block and the balance ring of the main slide valve. This ring had been broken into four pieces, and the wrist pin of the cut-off valve in two. The condenser leaked badly and made the feed water troublesome; there was no way to get rid of it except through the feed pump.

At San Diego, the ship was kept in readiness to steam out and no repairs were attempted. She started south about the seventh of May and met the *Esmeralda* outside of Acapulco, on the evening of May 15. During the run the engines hammered heavily and the condenser leak gave trouble. After leaving Acapulco she steamed south about one hundred and fifty miles and stopped about fifty hours to overhaul. One of the furnaces had gone down slightly. The fires were hauled, the boiler emptied, and a large collection of scale scraped off the furnace crowns. The thrust ring, *e*, was removed and several thin liners put in behind it. Other stops were made subsequently on account of the machinery. During the remainder of the voyage the engines hammered frightfully and salt water was freely used, being poured down the holes through the caps and brasses. No cut-off block was on the H.P. valve and the gear was entirely thrown out.

A constant lookout was kept and no lights were allowed. The greatest speed during the voyage, notwithstanding the fact that the engines and boilers were pushed to their utmost, was 9.1 knots, and the average was between 8 and 9 knots. After the arrival in Iquique, on June 4, the ship was surrendered to Admiral McCann, and a force of fifty men from the *San Francisco*, *Baltimore* and *Charleston* was placed on board under the

charge of three officers to get her ready for the return voyage. Tools and materials were freely supplied from the fleet to push the work, which was completed in five days.

The following brief summary of this work is added:

The whole shaft had gone forward one-quarter of an inch, and the crank webs were bearing hard against all main bearings and crank-pin brasses. The thrust ring was removed after great difficulty in getting the shaft back to its place. This was actually done by jacking the engine against two large steel wedges placed between the bed plate and the forward side of the L.P. crank; two heavy jacks had been tried between the bed plate and the balance wheel without success. Six or seven liners in the space marked *h* had slipped around enough to overlap one another and cause unequal bearing on the thrust ring. They were replaced by two brass liners equal in thickness to $\frac{3}{8}$ inch. The cast iron of the ring was cut away around the white metal for oil grooves. Each half of this ring had to be forced back into place with a ten-ton jack and a sledge hammer.

The four main bearings were brass bound and the shaft had nearly one-fourth inch play. The brasses were removed and chipped on the sides to give a good bearing in the crown. Leads were taken repeatedly to make sure of proper adjustment. Although the shaft was down considerably, there was no time to get liners under the bottom brasses, as that would have involved disconnecting everything and lifting the shaft about two inches. The crank pin brasses were removed and the after edges cut away $\frac{1}{4}$inch for end play. The shaft had gone forward enough to shove the connecting rod out of line and necessitate thicker liners on the after wrist pins of each engine. These liners were removed and the rods lined up. The H.P. wrist pins, which had worn oval, were chipped down each side well below the surface of a true circle and the brasses were all refitted. A composition balance ring for the H.P. valve was cast on shore from the cast-iron ring taken out; but it turned out too large and had to be planed on board the *Charleston* to fit the recess. The H.P. cut-off cross head was fitted on shore with a steel wrist pin and the cut-off block and gear were replaced. The balance ring was also

put back with rubber packing behind it. All stuffing boxes about the main engines were repacked. Four condenser bonnets were removed, the fresh water side filled with water and two tubes plugged. All the valves of the air and circulating pumps were examined and found in good condition.

The valves and cocks on the main boilers were taken down, ground in where necessary, repacked and new joints made. Many small seams were caulked and several securing bolts replaced. About one ton of scale and salt had to be chipped out of the combustion chamber of one boiler to reach a leaky seam. The crown sheets and tops of combustion chambers were well scaled and the bottoms of the boilers cleaned. A hydrostatic test of 70 lbs. (10 lbs. above the steam pressure) was also applied to the boilers by means of the feed pump run from the donkey boiler. Three lengths of copper piping with bad holes, one of them a feed pipe, were rebrazed.

The voyage to San Diego in company with the *Charleston* was made, without stoppage of any kind due to the machinery, at the rate of $8\frac{3}{4}$ knots and about 44 revolutions. The ship could have made 10 knots, but the above was selected for economy of coal on both ships. Indicator cards taken at intervals disclosed bad setting of the H.P. main valve, a slight negative lead causing hammering on the lower center. Three officers and ten men from the *Charleston* accompanied her north. After anchoring in San Diego, the L.P. valve-chest bonnet and the main stop valve were taken on shore by the United States Marshal to disable the ship.

## XIV.

## METHOD OF MOULDING IN LOAM AND CASTING THE CYLINDERS FOR THE CRUISERS *CINCINNATI* AND *RALEIGH* AT THE NAVY YARD, NEW YORK.

By Passed Assistant Engineer Geo. H. Kearny, U. S. N.

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The cylinders and steam chests are in one casting; the cylinders are unjacketed except on the lower or solid head and only the H.P. cylinder has a wearing liner. All the steam chests have separate cast-iron wearing liners, which were cast with the ports in them.

The following description refers to one of the L.P. cylinders:

From the dimensions given on the drawings a foundation or bottom plate was cast in open sand, of such size as to cover the projected area of the cylinder, steam chest, &c., and to allow for an eight or twelve-inch wall around them.

This plate has lugs and staples by which to bind the mould together and to lift it, and openings through the plate to allow for venting and securing the main cores.

It was cast three (3) inches thick to give sufficient strength and rigidity, as it had to support the whole weight of the mould.

The foundation plate was put in place and leveled, then the iron spindle, about three (3) inches in diameter was placed in position, the foot fitting into a socket bolted to the plate, and the top secured by an arm and braces from the foundry wall.

The vertical position of the spindle was verified by a plumb line and then an arm or "wing" was bolted to the spindle for the purpose of carrying the different "sweeps."

The foundation plate was covered with a layer of brick, on top of which was spread about one-half inch of loam, and a bearing swept up for a guide for the outer part of the mould, and for the lifting ring to rest on.

Center lines, at right angles, were laid out on this seating and the ends transferred to the plate by means of the gauge stick and a plumb line and there marked with a chisel for use in case of the lines becoming effaced in the seating.

Seatings to carry the steam chests were next laid out, their position being determined by means of the center lines and the "gauge stick." This gauge stick is notched in the center so as to allow its center to coincide with that of the spindle, from which point distances are measured, and on it were laid off with the shrinkage rule the different dimensions required.

Horizontal pipes were laid at the bottom of the steam chest seatings, to serve as vents, and the seatings were built up with bricks to the proper height and covered with loam. The bricks were laid with fine cinders between them to give a chance for the gases to escape while pouring the metal.

The flange sweep was next attached to the "wing" and the main flange of the cylinder swept up to size, as given by the gauge stick, with floor sand mixed to a consistency of mud, having "spauls" or chippings of brick mixed in to harden the mass, and then swept up with "slurry" or fine loam sand made liquid and run through a $\frac{1}{8}$-inch mesh sieve.

A "dummy" was next built and swept up, corresponding to the circular part of the outer surface of the cylinder, extending from the flange to the top of the jacketed head, as shown in Fig. 1, which also shows the valve-chest seatings, and the foundation and lifting plates.

The "dummy" was built hollow, with one course of brick and a light plate placed near the top to carry bricks and loam, which is swept up to correspond with the outer surface of the solid head.

This top plate was slotted radially, to allow it to pass the spindle, and was small enough to allow its edge to be covered with mud to give it a surface.

The dummy was faced with mud, as the bricks absorb the moisture quickly, causing it to harden, and then smoothed over with fine "slurry."

The dummy having been completed, the center lines were transferred to it by means of the gauge stick and plumb line.

Great care was taken to have the dummy the right size, as all the patterns for steam chests, brackets, cylinder feet, ribs, &c., were set up to it.

A "lifting plate" or ring was next cast in open sand, of suitable shape and size to enclose the dummy and to carry all projecting parts of the steam chests, &c. This plate has lugs and staples to allow of its being lifted and for binding the parts of the mould together.

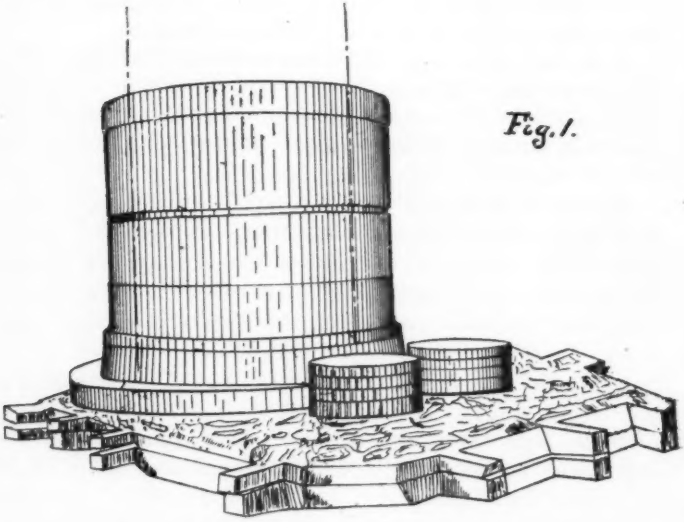


*Fig. 1.*

The lifting ring was placed on the seating previously swept up for it, and the lower part of the pattern for the steam chest was placed in position on the valve-chest seatings, and the loam and brickwork built up to it, as shown in Fig. 2; after which the patterns for the rest of the steam chests, nozzles, exhaust passages, ribs, cylinder feet, brackets, &c., were laid up to the dummy, their position being determined by means of the center line on the dummy; thus was produced an exact shape or pattern of the outer surface of the whole cylinder.

The surfaces of the dummy and of the wooden patterns were

then oiled to prevent the loam from sticking fast to them, and the work of building up the mould proper was begun.

The loam used was a mixture of two (2) parts of coarse moulding sand to one (1) of coarse fire-sand, with one-tenth ($\frac{1}{10}$) part, by measure, of dry horse manure, the whole being thoroughly mixed together and then passed through a quarter-inch mesh sieve, after which it is mixed with a thick clay water to the consistency of mortar. The manure is used to make the loam porous.

A facing of about one-half ($\frac{1}{2}$) inch of this loam was laid on the dummy and patterns, and the bricks laid up to it; the bricks were bedded in mud made of the ordinary floor sand; the brickwork was generally eight (8″) inches thick, except where necessary to support overhanging parts, when the thickness was increased accordingly. All joints and interstices in the brickwork were filled with fine cinders, and at narrow points and corners straw was laid, the object of thus making the mould porous being to allow the ready escape of the gases generated when the metal is cast, so that the surface of the mould will not buckle or "scab," and to assist in thoroughly drying the mould while in the oven.

Where there were any narrow or weak points in the mould they were strengthened by "gaggers" or "anchors" made by bending $\frac{3}{8}$-inch or $\frac{1}{4}$-inch iron rods to the required shape and size, and securing them in the brickwork.

In building up this mould it was necessary to divide it at parts (such as the steam chests) into different sections or "drawbacks," to allow of the patterns being withdrawn and the cores being placed in position. The "drawbacks" were built up on plates cast in open sand to the proper shape, and having a similar plate laid one course of bricks from the top of the "drawbacks", the two plates being secured together when in position by means of hook bolts through staples, so as to form one solid mass.

The seatings for the "drawbacks" were made by covering the brickwork with loam and smoothing it, and when this was dry "slurry" was laid on and slicked smooth, and when dry was

oiled and parting sand sprinkled over it. On this seating was laid about an inch of loam, in which was bedded the "drawback" plate, having prickers on the under side as well as on the top, the plate having been clay washed to make the loam adhere to it.

On this lower plate the loam and brickwork for the "drawback" was built up.

These "drawback" plates were laid at a level with stiffening plates in the adjoining parts of the mould, and were afterwards bolted to them to give strength to the mould while the metal was being cast.

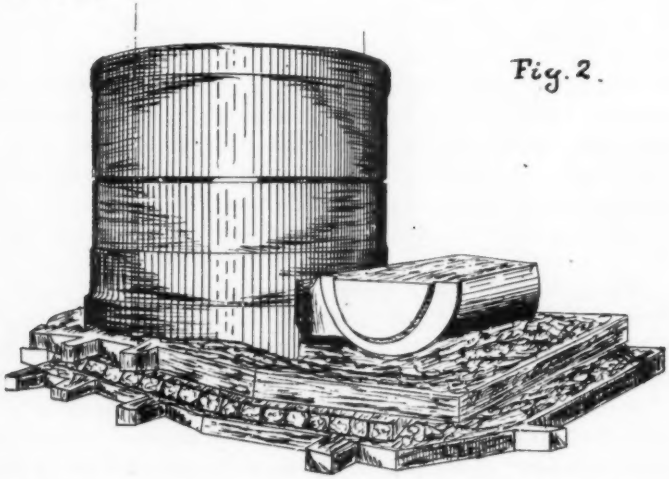


Fig. 2.

In building the mould the drawbacks were left to the last, as the joints or partings have to be prepared.

Cast-iron stiffening rings were bedded in the mould as it was built up, and when the last plate was bedded the whole mass was firmly secured together by hook bolts to the lifting plate, scores having been left in the brick work above the lugs and staples on the lifting plate for this purpose.

For the space between the cylinder and the exhaust passages two special plates were cast, having long prickers in them. The

lower one of these plates was supported from the "drawback" plates, and had the loam and brickwork built on it up to the dummy and patterns, but leaving space for the vertical strengthening rib connecting the cylinder and the steam chests at this part. These plates extended across the rib, and had the center parts cast into the rib, after which the ends were broken off.

The main "drawback" extended from the middle of the lower steam nozzle to the middle of the upper steam nozzle, and from the line of the cylinder foot around to the other side of the cylinder, as shown by broken lines on Fig. 3.

Care was taken to leave openings where the steam and exhaust nozzle cores cut through the sides, in order to secure the cores in place, and for inserting pipes for venting and conducting away the gases through the sides of the mould.

In order to have an equal distribution of metal throughout the mould when casting, especially around the steam chests, "runner sticks" were built in the spaces, being connected afterwards with the draw gates which conducted the metal into the mould.

The outside of the mould having been finished, the spindle was removed and a top or covering plate was cast in open sand, having openings in it for all parts of the mould that may project above it. As it bedded at the middle of the top steam port, openings were left for this port, the cylinder feet or lugs, &c., and for securing and venting the cores for the steam chests, steam jackets, piston rod, manhole, &c.

There were also openings for the gates in line with the thickness of the body of the cylinder leading to the top and bottom of the mould. These various openings allow parts of the different patterns to be withdrawn and give the moulder a chance to dress and finish the mould, and were afterwards covered by smaller plates secured by hook bolts to staples cast in the top plate.

Prickers or prongs were cast in the bottom side of the top plate, and the plate was fitted in place to see that these prickers were of the right length, the ends conforming closely to the top surface of the dummy cylinder.

The plate was inverted and bricks were wedged tightly between the prongs, so that they could not fall out when the plate was again reversed; the surface of the bricks was covered with a thin layer of loam; the plate was then put in the oven and dried. Sharp spikes were driven into the center of each core-print or jacket opening to serve as a guide for corresponding hole in the top plate. When the top plate was removed from the oven, it was placed on the "dummy" and fitted by rubbing and scraping till it had a good bearing.

This having been done, the top surfaces of the "dummy" and patterns were oiled and then covered with one or two inches of loam, and a clay wash put on the dry loam surface of the top plate to make the wet loam adhere to it. The top plate was inverted and lowered on the wet loam and gently rubbed to and fro to make the loam take a good impression of the cylinder and to squeeze out any extra loam; the closer it is rubbed down the better, as there would be the less moisture left to be absorbed.

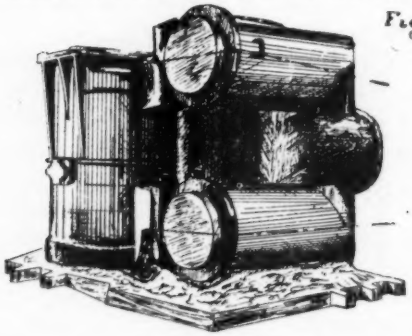


Fig 3

Where there were any vacant spaces, as around the cylinder feet, "gaggers" were fitted in and bedded in the mass on the top plate and the openings then filled with loam.

The joints where the mould was to be parted were sleeked smooth and marked so as to serve as guides for connecting the parts again, and the top plate was then removed and inverted, it having trunnions on it to allow of this being readily done, and the surface of the loam was dressed and finished.

The inside "dummy" was next removed by picking out the bricks and removing the dry mud, and, if the loam surface showed any irregularities, the spindle was put in place and a sweep used to straighten it.

The patterns for the steam chests, brackets, ribs, &c., were next carefully removed, either whole or in sections, the drawbacks lifted away and the pattern for the lower part of the steam chest withdrawn, when the "drawback" was replaced and secured to the stiffening plates and lifting ring.

A strong iron crossbeam having been attached to the foundry crane was swung over the mould, and links or slings from it were connected to the lugs or staples on the lifting plate and this was then lifted off the foundation plate, care being taken to lift it squarely off its seating by attaching counterbalance weights to the crossbeam opposite the heaviest side of the mould. The crossbeam has notches on the top sides to prevent the iron slings from slipping.

The mould was placed on a car convenient to the oven and finished by smoothing the uneven surfaces; filling up any crevices or hollow parts with loam, and the whole surface then washed over with a preparation of fine loam; the surface sleeked smooth with trowels or different shaped sleekers and then given a coating of liquid blacking applied with a brush.

This blacking consisted of six (6) parts of pulverized charcoal, two (2) parts of mineral facing, two (2) parts of silver lead or graphite; the whole mixed with clay water, to which was added one-half gill of molasses.

For an extra finish the mould was again sleeked over and a camel's-hair brush used to wash it with a mixture of molasses water and graphite. This prevents the blacking from rubbing off after the mould has been dried.

This wash prevents the metal from burning into the surface of the mould. The top part of the mould was treated the same way.

When the "lifting plate" was removed a covering of loose sand was put over its seating to protect, it and the building up of the main core began.

The spindle was put into place and a sweep attached at a radius to allow for shrinkage and for boring out the cylinder. The main core was built up with a double row of bricks next the sweep and the center part part filled with loose bricks having

fine cinders between them, to allow of free passage of gases to the vents through the openings for the piston rod and manhole, as there would otherwise have been danger of an explosion due to the accumulation of hot gases mixed with the air.

The top was strengthened by a "crown" plate having prickers in it to hold the bricks and loam forming the top surface of the main core. This "crown" plate had a radial slot in it to allow it to pass the spindle, the slot being afterwards covered by a small covering plate bolted to the "crown" plate. One of the most important points in building the main core was the "relieving bar," which reached from the bottom flange to the inner thickness of the jacketed head, and was placed directly under the manhole opening.

This relieving bar was of iron, tapering from $\frac{3}{4}$ inch at bottom to $1\frac{1}{2}$ inches at top and 8 inches wide. A hole near the top of the bar allowed a shackle to be attached and the bar withdrawn through the manhole, after the cylinder was cast, so leaving a clear space for the contraction of the metal while cooling.

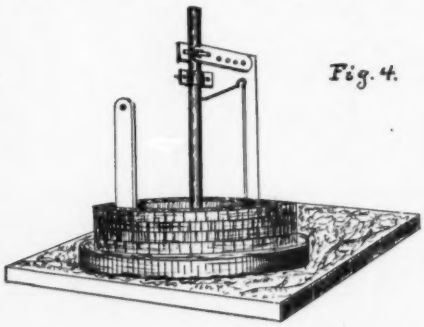
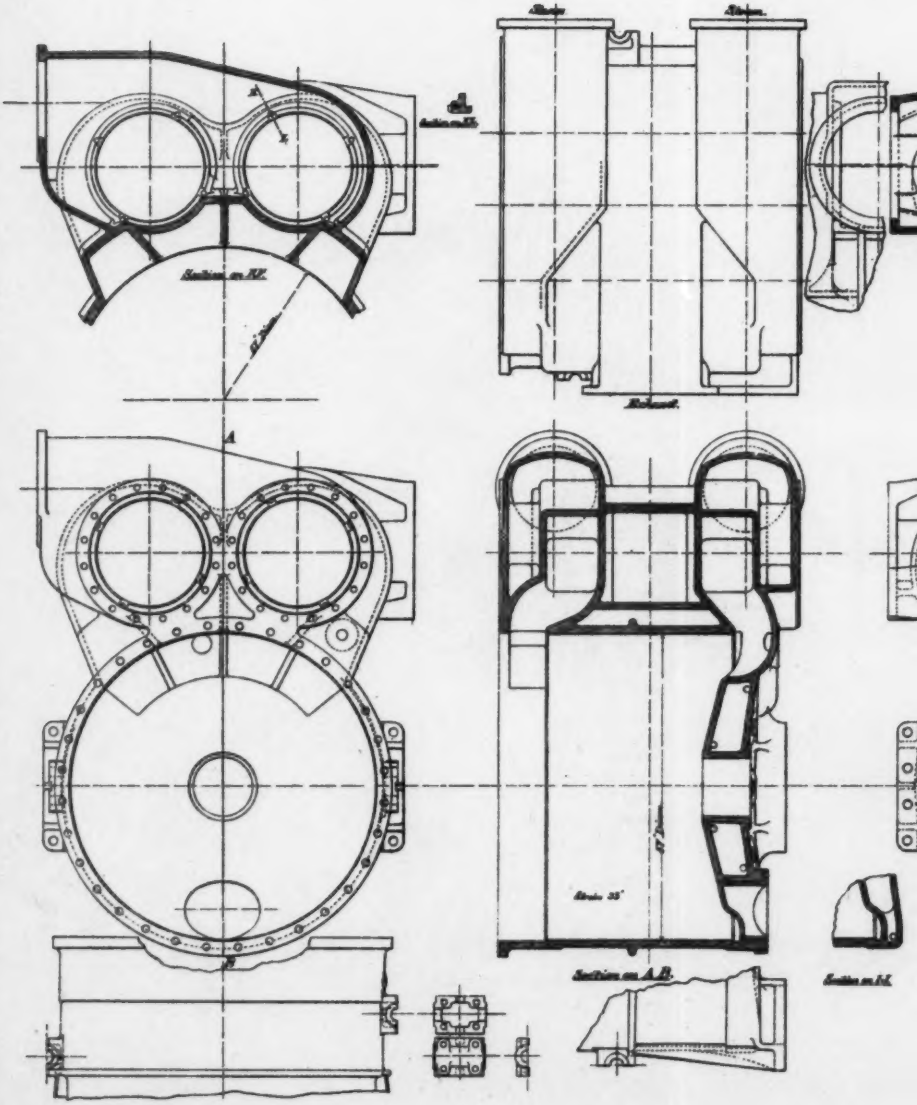


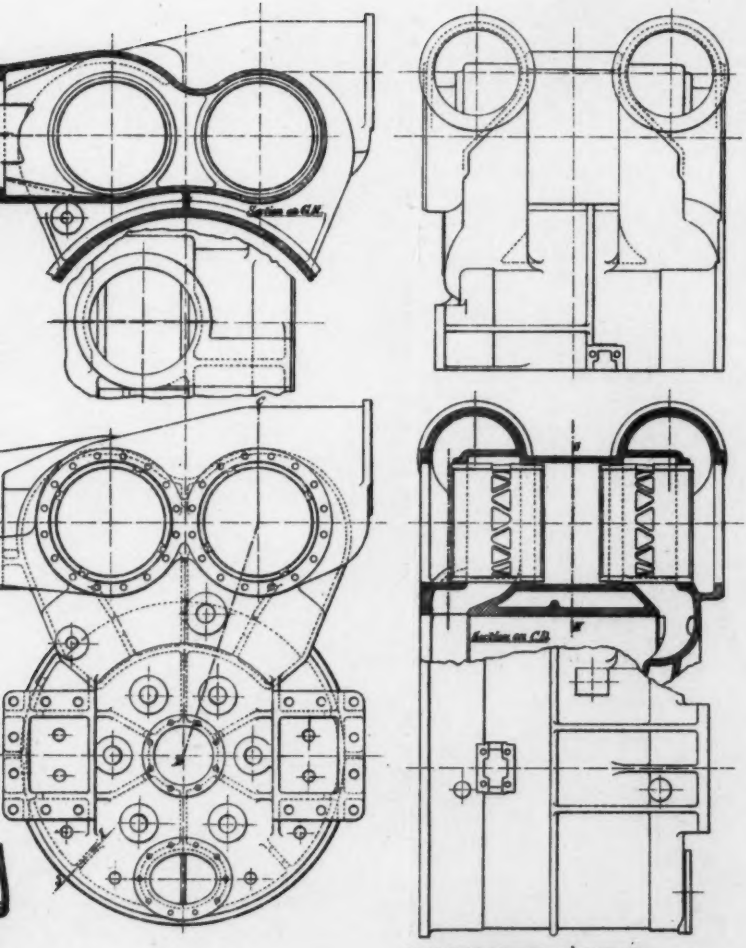
*Fig. 4.*

The bar was placed with its narrow edge flush with the surface of the bricks. Fig. 4 shows this relieving bar while the main core was being built up.

Part of the port cores were swept up on the main core, to which they were secured by prickers on the "crown" plate, they being located by means of the center lines, and made to correspond exactly with the dry sand port cores in the steam chests.

The main core was made a little larger in diameter at the bottom than at the top, to allow for the pressure of the molten metal; the pressure being due to the height of the cylinder plus that of the riser head. In these cylinders $\frac{1}{8}$ inch






LOW PRESSURE CYLINDER.

for

U.S.S. RALEIGH.

Designed by Bureau of Steam Engineering, Navy Department.

Chief of Department Steam Engineering

Navy Yard, New York.

was allowed. This precaution also helps to prevent the core from floating.

In some shops an internal bearing is secured to the "foundation plate" and the main core built on it, so that when completed it can be lifted out and the moulder examine the cores for the ports, &c., and see that they are in place and have the right space for thickness of metal around them.

After verifying the dimensions of the main core, the spindle was removed, the core blackened and finished similarly to the other parts of the mould, when all parts were transferred to the oven, the joints having been blocked open to allow of the circulation of the hot air. It is best to dry the mould slowly at first to prevent too sudden expansion of the different iron plates, &c., and the blistering and cracking of the finished surfaces.

After about twelve hours the heat can be increased, care being taken that the mould is not burnt. It takes from forty-eight to seventy hours to completely dry the mould, which should then have a light brown color.

While the foregoing work was being done, the "dry-sand" cores were being prepared. Wooden core boxes of the requisite shapes were used to make the steam chest and other cores.

Where the cores had to be rights and lefts, the boxes were made interchangeable. Core irons were cast to the shape of the box for stiffening the cores, and had staples for lifting cast in them, also "prickers" of wrought iron for holding the sand together. The core irons were made gridiron or herring-bone shape as more convenient for ramming the sand and easier to break out after the cylinder is cast. These irons had a feather or "V"-shaped edge, so as to present the least possible resistance to the shrinkage of the metal.

The sand used was composed of eight (8) parts of fire sand and four (4) of coarse moulding sand, with one (1) part of flour. If the sand is very moist one-half part of ground clay is added. The whole was well mixed together, then passed through a $\frac{1}{2}$-inch mesh sieve and afterwards through a $\frac{1}{4}$-inch sieve, then moistened with clay water and tramped or kneaded thoroughly, and finally again passed through a $\frac{1}{4}$-inch sieve. The sand must be of the

right consistency; if too dry, the core may crumble when dried; and if too wet, it will swell or crack in drying.

The flour and clay cement and bind the particles of sand together when baked in the oven; and, in the casting of the metal, the flour burns away and disintegrates the core, making it easier to remove.

Everything being ready, the core-box, for example, that for one of the steam port cores, was laid on a solid foundation, and some fine core sand sifted through a $\frac{1}{8}$-inch sieve over the bottom of the box; on top of this was placed a layer of sand $\frac{1}{2}$ inch to 1 inch thick, and then the core iron having been clay-washed, was hammered down in the sand, and the sand rammed all around it and between the spaces in the core iron. Where there were any large open spaces, points or corners, rods or nails were bedded in and wired fast to the core iron to strengthen such weak parts.

The core having been rammed several inches deep, all parts were vented with a vent wire and the center of the box filled with cinders.

The core was thus built up till the top of the box was reached, when the top surface was vented into the cinders, the surface squared, moistened with clay water, sleeked smooth, blackened, and then had some dry parting or beach sand sprinkled over it, on which was packed some damp moulding or floor sand of sufficient thickness to cover all the projecting parts of the core iron, and a stiff plate large enough to cover the whole, bedded in the sand and clamped fast to the core box. The mass was then inverted, the core box loosened by rapping and carefully drawn off. The surface of the core was next finished and placed in the oven to dry.

The steam jacket cores were made in the same way, the core irons being cast from patterns and made very light, as they have to be broken up and drawn out of small holes after the cylinder was cast. A thread was tapped into these core irons and a tube bolt screwed in, answering as a vent and also to secure these cores to the top plate.

In building the cores, strings were run through them above

the core irons and passed through saw-cuts in the edges of the core boxes. After the core is finished in the box these strings are pulled out and the cores tested by puffing smoke or flour through the openings left—if clear the cores are used, but if not clear it shows that the core is not well vented and must not be used.

These holes are afterwards sleeked over with "slurry." In building up the main steam-chest cores, a wooden plug was built in the center of the core from the bottom to the top, which, when withdrawn left a clear vent to which all the port cores opened by means of their cinder centers.

The casting pit was dug in the floor of the foundry, where it could be readily reached by the cranes, and was of sufficient size to allow of a curb of sheet iron to encircle the mould. The sand thrown out was afterwards used for ramming purposes, so only about one-half the depth of the mould was necessary in the pit. The bottom of the pit was levelled to give a fair seating for the foundation plate.

Sometimes a channel is cut from the center of the pit and filled with cinders to conduct the gases from the main core, as the opening at the top may be too small for that purpose.

The mould and cores having been thoroughly dried, the foundation plate carrying the main core was placed in the pit, and all dust and dirt cleaned off, and the edges of all joints scraped to prevent shelling off or crushing when the other parts of the mould were put together. Generally the edges of the joints are scraped before the mould goes into the oven.

The lifting plate carrying the rest of the mould was next lowered into place, and the space for the thickness of metal gauged by putting in rolls of putty or soft clay and taking impressions of the thickness on them.

This thickness space being correct, the "drawbacks" were removed and the cores for the steam-chest nozzles, steam and exhaust ports were put in position, great care being taken to see that the proper thickness of metal was allowed for all round; that the cores matched properly and were exactly in their proper place. Cast-iron chaplets were placed in the thickness space be-

tween the cores, to serve as supports for the cores and to enable them to resist the pressure while the metal is being poured.

The chaplets are usually made of cast iron, being two plates connected by a stud of as small a diameter as possible, as it expands as the metal flows around them, contracting again when cooling and liable to show leaks when testing the cylinder. These chaplets are generally tinned or zinced over to give better joints in the casting.

It is necessary to be very careful of the joints where the different cores connect to the main steam-chest core, to prevent the metal from forcing its way into and choking the main vent should the cores happen to shift at all. To prevent this, short iron pipes of about the size of the wooden plug used in building up the steam-chest core are placed abreast of the joints, and damp facing sand rammed between the tube and the cores, completely filling the joint. Soft putty is also used for the same purpose, a thin roll being placed around the joint where the two cores connect, the putty helping to even up the thickness by being used thick or thin. The vent opening is filled with cinders to prevent it being choked, and to allow the gases to flow off regularly to the surface.

As the cores are placed, the "drawbacks" and "pockets" are put in their proper position.

The jacket cores were next secured to the top plate by means of the tube bolts tapped into the core irons (these bolts were protected by small hollow dry sand cores) and carried through openings in the plate; chaplets were used to retain the proper space between the cores and the top plate. The top plate carried the steam jacket, manhole and piston-rod opening cores; these having been secured in position, the top plate was inverted; soft clay balls placed all over the top surface of the main core, &c., to try the thicknesses, and the top plate lowered into place, and then removed, and the thickness space for the metal having been found correct, chaplets of the right size were placed where required, the clay balls removed and the top plate replaced in position.

The mould was prepared for binding and clamping together

by stopping the joints and partings with slurry and inserting tubes into the cores to carry off the gases to the surface.

Iron packing or distance pieces were placed between the foundation and top plates to prevent the mould being crushed while being clamped and bolted together.

The heavy iron crossbeam was then swung over the mould and secured to the foundation plate by iron links or slings, leaving about three feet between the bottom of the cross and the top plate; then the whole mass was tightened by lifting with the crane; iron packing or stays were placed between the cross and the top plate, one in the center and one under each of the four arms and finally the whole tightened by driving in iron wedges.

A few iron clamps were added to help the cross resist the pressure, especially around the steam chest, where there is an extra pressure from the cores.

The next process was placing the "curbing" around the mould; this consists of a cylinder made of thin sheet iron from one to three feet wide, the sheets being keyed or bolted together to form a cylinder, leaving about eight to sixteen inches between the mould and the curb. Vent sticks were placed to lead the gas to the top, and straw also placed against the brickwork for the same purpose.

A course of sand eight or ten inches deep was thrown inside the curb, rammed down hard and then other layers added till the top of the curbing was reached, additional sheets being added as necessary. The sand at the bottom requires to be packed and rammed vary hard with heavy iron-butt rammers, as there is a heavy pressure at that point. This is also done between the curbing and the side of the pit, which is also filled in.

The moulders used a pin rammer to ram the corners, and, as the sand was filled in, saw that the vent sticks were kept in place and new ones added where necessary.

The top of the curbing was about twenty inches above the top surface of the casting, to allow for a basin to pour the metal into, and a runner or flume to lead the metal to the gates; the bottom of the runner should be twelve or fifteen inches above the surface of the casting to insure a uniform pressure and to force

the gas through the mould and cores; also to prevent the molten metal from bubbling and blowing by forcing it through the rising heads, which are flow-off gates placed generally on the highest and thickest parts of the casting for the purpose of feeding the shrinkage of the casting while it is in a liquid state.

The runners were next prepared by inserting "gate sticks" in the openings that allow the metal to flow into the mould; the vent openings secured by placing in them tubes large and long enough to prevent either dirt or metal from entering and choking them.

Some well-sieved, well-tempered moulding sand was packed and given a fair ramming for a depth of about fifteen inches, where the runners and basin were to be and also around the gates and risers, the surface levelled and packed by tramping over it. The basin was made about twenty-five inches diameter, and the channels from four to five inches wide and eight or ten inches deep, connecting the basin to all the gates. A flat, dry sand cake is usually placed in the bottom of the basin to prevent the stream of metal from the ladle cutting out the bottom. The surfaces of the basin and runners were smoothed and blackened, all loose sand and dirt cleaned away, and a place cut out around the risers, to hold about one hundred pounds of metal. Lumps of stiff clay, having lifting hooks in them, were placed over the risers and weighted down, to keep a pressure of air in the mould while the metal was being poured.

Shavings and straw were placed in the vents, and lighted just before the metal was poured, to ignite the gas.

The amount of metal necessary was calculated from the drawing, allowance made for metal to fill the gates, runners and risers, and then a surplus added to cover any accident or miscalculation; this surplus was afterwards cast into pigs.

The iron for steam cylinders should be very tough, strong and close grained. A good mixture is one-third of No. 1 American charcoal iron, with two-thirds of good machinery scrap, or if the machinery scrap is soft it will not require the pig iron, the melting bringing it down to the required strength. The metal used

for the cylinders of the *Cincinnati* and *Raleigh* was all good machinery scrap.

The temperature of pouring the metal is very important. If too hot, the metal is more fluid, and has a greater penetrating power, and if there are any defects in the mould the iron is liable to find them out and create trouble; if too cool, the casting may show air or dirt holes while being machined, the metal not having sufficient fluidity to throw off the gas or float the dirt to the surface. The metal should be received hot from the cupola, and when cool enough to hang on an iron rod, should be run into the mould.

In pouring the metal the scum in the ladle was first skimmed off, then the metal poured slowly till the bottom of the basin was covered, then the stream increased, filling up the runners and keeping any dirt or scum floating on the surface till the mould was filled, which was indicated by the air blowing through the gates and risers, then the clay stoppers over the risers were lifted and the metal allowed to flow through, meanwhile keeping the runners full to increase the pressure.

When the metal in the runners became solidified, it was broken into pieces and thrown to one side, the sand cleared off the top plate, the iron crossbeam hooked on to the crane, and the iron packing knocked out from under the beam; the way cleared down through the manhole to the relieving bar, which was hooked on to the crane and pulled out, to relieve the main core and prevent any danger of the cylinder cracking as the metal shrinks while cooling. The steam chest and nozzle cores were also relieved by having the cores partly broken up.

The curbing and sand were then removed and the outer parts of the mould relieved to prevent any interference in the shrinkage of the metal around such parts as the feet, brackets, &c.

The immediate safety of the casting having thus been provided for, it was left till the following morning, when it was still red hot, and the core irons of the steam chest cores were broken from top to bottom by working through the steam chest openings. After three days the casting was cool enough to take out of the pit by breaking away the brickwork, burnt loam, plates,

&c.; the cylinder was cleaned, all cores removed and all risers, fins, &c., chipped off.

Either before machining, or else afterwards, all parts where the steam comes in contact with the surfaces which are not machined, should be thoroughly pickled with a solution of muriatic acid in order to clean away all sand and grit that is partially burnt into the metal.

Great care was exercised by the moulders throughout the work, and the pattern makers who had made the patterns, sweeps, &c., constantly verified and corrected the sizes, locations, &c.

The above was the method adopted in casting the cylinders for the engines of the *Cincinnati* and *Raliegh*, and it proved very successful as not one was lost of the sixteen cylinders cast.

While being machined, the inside of the solid head and cylinder cover should be carefully gone over with a template or sweep to see that they are counterparts of the piston, as in moulding there may have been some irregularities of the surface which would diminish the clearance in the cylinder.

The finished weight of one of the L.P. cylinders is eleven thousand six hundred pounds.

The writer is indebted for valuable assistance in the preparation of this article to Mr. William Forbes, the master moulder in the Steam Engineering Department of the New York Navy Yard.

# XV.

## FEED-WATER HEATING.

By Assistant Engineer Thos. W. Kinkaid, U. S. Navy.

With the advent of the triple-expansion engine came its legitimate accompaniment, the high-pressure boiler, and with high pressures came the necessity for heating the feed water. The temperature of saturated steam of 175 pounds pressure absolute is 370.8° F., while feed water is frequently at so low a temperature as 110° F. We have then a cool current of water taking a devious course amongst the other water of the boiler, impinging in its wanderings against hot heating surfaces, subjecting them to sudden contraction, or against columns of steam bubbles on their way to the water line, effecting their condensation and perhaps inducing foaming. In fact a current of cold feed water must be rated as one of the worst disturbing elements that a boiler has to contend with.

In shell boilers which have neither appliances for heating the feed nor means for producing a thorough circulation, a body of comparatively cool water settles at the bottom and does considerable mischief. The modern double-ended boiler attains a length of about 20 feet. In the case of such a boiler, if the temperature of the water at the bottom be 150° F. and the temperature of the upper portion of the shell be 370° F. (corresponding to steam of 160 pounds per gauge), the difference of expansion between the two opposite parts of the shell amounts to about 0.33 inch. The strains thus set up are well known to be the cause of many leaks and fractures. With feed water heated to live-steam temperature, such strains are entirely obviated. In some cases the feed water is not heated up to the live steam temperature, the benefits of such treatment being, of course, proportionately less.

For heating feed water three methods have been tried, viz:

Class A.—Arrangements of pipes or flues in uptakes.

Class B.—Arrangements of feed coils surrounded by exhaust steam from receivers or live steam.

Class C.—Direct commingling of the steam with the feed water without the intervention of heating surfaces.

Devices in class A have long been in use. The objections to them are: liability of the heating surfaces to burn from being fouled with scale, grease, or other dirt; liability to corrosion from the effects of moisture, acids in the furnace gases, and so on, and also inaccessibility for effecting repairs.

The other two forms—classes B and C—are the ones now most commonly in use, and it is not improbable that uptake heaters will eventually be discarded even in shore plants.

For class B it may be said that the arrangement of tubes acts to a certain extent as a grease extractor, the grease adhering to the tubes, from which it may be removed periodically. With the increasing employment of oil eliminators on the exhaust pipes of engines, it is not likely that the feed water of the future will contain much, if any, oil. Should the feed water contain any scale-making constituents, the hot tubes will precipitate and receive the same and thus save the heating surfaces of the boiler. Against this class of heater may be noted its somewhat complicated structure, its expense, and the inconvenience of cleaning and scaling.

Those forms of heaters under class C are the simplest of all, just as the old jet condenser was simpler than the modern surface condenser. By heating the feed with direct contact of steam a smaller apparatus is made effective, since there is no transmission of heat through slow-conducting metals. If the heater is to be employed in the double capacity of heater and scale precipitator, then there must usually be provided a series of plates or pans, to receive the precipitate, the heater being opened at intervals and the pans removed for scaling. In this case, there is probably but little saving in weight over class B. The scale pans of class C are somewhat more convenient for removal and scaling than are the tubes of class B, and the matter of expense is probably slightly in favor of class C.

Since steam is used as the heating agent in two of the classes of heaters under consideration, it becomes important to inquire whether the heating should be accomplished entirely with live steam or partly with exhaust steam and partly with live steam. We shall first assume that one pound of feed water is heated up to the live steam temperature by the employment of live steam alone. Next we shall consider one pound of feed water heated up in successive stages by steam from L.P. receiver, steam from I.P. receiver, and finally by live steam.

I.—To heat 1 pound feed from 110° F. to 370.8° F., with steam of 175 pounds pressure absolute and temperature of 370.8° F.:

Number of heat units to be imparted = 260.8.

Number of heat units to be surrendered = $855.6\,x = 260.8$.

Number of pounds steam condensed = $x = 0.3048$.

Total pounds feed sent to boilers = 1.3048.

II.—(*a*) To heat 1 pound feed from 110° F. to 228° F. with steam from L.P. receiver of 20 pounds pressure absolute and temperature of 228° F.:

Number of heat units to be imparted = 118.

Number of heat units to be surrendered = $954.9\,x = 118$.

Number of pounds of steam condensed = $x = 0.1235$.

Number pounds of augmented feed water = 1.1235.

(*b*) To heat 1.1235 pounds feed from 228° F. to 302.9° F., with steam from I.P. receiver of 70 pounds pressure absolute and temperature of 302.9° F.:

Number of heat units to be imparted = 84.15.

Number of heat units to be surrendered = $902.9\,x = 84.15$.

Number of pounds steam condensed = $x = 0.0932$.

Pounds of augmented feed water = $1.1235 + .0932 = 1.2167$.

(*c*) To heat 1.2167 pounds feed from 302.9° F. to 370.8° F., with steam from boiler of 175 pounds pressure absolute and temperature of 370.8° F.:

Number of heat units to be imparted = 82.61.

Number of heat units to be surrendered = $855.6\,x = 82.61$.

Number of pounds steam condensed = $x = .0965$.

Total feed = $1.2167 + .0965 = 1.3132$ pounds.

In case I, one pound of steam passed successively through the

H.P., the I.P. and the L.P. cylinders. In case II, 1.2167 pounds steam passed through the H.P. cylinder, 1.1235 pounds passed through the I.P. cylinder and 1 pound passed through the L.P. cylinder. Since, in all properly adjusted triple-expansion engines, the work is divided more or less equally among the three cylinders, we may, for the purposes of comparison, assume that one pound of steam performs the same amount of useful work in each one of the cylinders through which it may pass. Then, in case I, the work would be represented by $1 + 1 + 1 = 3$. In case II, the work done would be represented by $1.2167 + 1.1235 + 1 = 3.3402$.

Placing these results in tabular form, we have:

| | Heating by live steam only. | Progressive heating. |
|---|---|---|
| Total pounds feed sent to boiler, . . | 1.3048 | 1.3132 |
| Number heat units surrendered to heat feed, | 260.8 | 284.76 |
| Number pounds steam condensed to heat feed, | .3048 | .3132 |
| Comparative work done in cylinders, . . | 3.00 | 3.3402 |
| Work done per pound of feed, . . . | 2.299 | 2.543 |
| Gain by progressive heating, . . . | ..... | 10.6 per cent. |

Whether the increased economy to be anticipated by the adoption of progressive heating will warrant the increased outlay for three heaters instead of one is still an open question.

As to the absolute economy of feed-water heating, it is not difficult to understand why uptake heaters should effect a saving, as the heat which they utilize would otherwise pass up the smokepipe and be wasted. But no one could anticipate that heating with either live or exhaust steam would reduce the coal consumption for a given power. Steam feed heaters were at first employed to relieve the boiler strains consequent upon the employment of cold feed water. The resultant economy of the practice was a surprising discovery. Much testimony can be adduced to prove the claims of economical gains from the employment of feed heaters, but the writer will content himself with a single quotation from the "London Engineer" of July 3, 1891:

"No experiments were made until after the *Oriole* had left

Blackwall, and could steam full speed without much chance of having to slow or stop. With the steam off the heater, and the feed temperature 140°, the pressure was 92 pounds, and the engines made thirty-four revolutions per minute. The firemen were fresh, and certainly did not spare themselves. And here we may say that all four—two being on watch at a time—were considerably above the average both in physique and skill. The pressure, however, did not rise above 92 pounds, and was kept there, indeed, with some difficulty. At the end of about three-quarters of an hour steam was turned into the heater. The temperature of the feed began to rise, and in about a quarter of an hour attained 320°. The boiler pressure steadily rose to 97 pounds and remained there. Obviously the work of firing was easier. The men could put down their shovels for a few minutes, and the rakes were not in requisition. We prolonged this experiment until there could be no doubt about the facts. The revolutions rose to 35½, an increase of a revolution and a half. We then had the steam turned off the heater with the result that the pressure began to fall, went back to 90 pounds, and was only got to 93 pounds by the vigorous use of firing tools. Once again we had the heater put into use, and the pressure was got up for some time to very nearly 100 pounds, and the revolutions rose to 36. Again, later in the day, the heater was thrown out of use, and the prickers were soon at work to push steam. The remainder of the trip was made with the heater in use."

To assign reasons for the economy obtained by feed heating is rather a difficult matter. If it be true that doing away with a stream of cold feed water in a boiler reduces the tendency of that boiler to prime, we can easily understand that there would be a slight economical gain due to the supply of drier steam to the engine. The increasing use of feed heaters in the merchant marine tends to confirm the claims for economy made by the manufacturers; and a larger experience with them will doubtless bring out the true explanation of their satisfactory performance. In the meantime, in the absence of crucial experiments, we are almost forced to the conclusion that water of the temperature of the boiling point has a remarkably high capacity for

the absorption of heat from any heating surface with which it may be in contact, thus enabling a boiler with a given ratio of heating to grate surface to perform as economically—that is, to cool the gases of combustion as effectively—as a boiler with a much higher ratio not provided with a heater.

## DESCRIPTION OF VARIOUS FEED HEATERS.

### CLASS B.

*Kirkaldy's heater.*—This consists of a vertical cylindrical shell, provided with heads or tube plates, in which are expanded the ends of spiral coils made from fluted copper tubes. It is claimed that the large surface provided by the fluted tubes is more efficient when employed in a coil than when the tubes are straight. The tube heads are bolted in place, and can be removed with the tubes when the latter require cleaning or scaling. When employed as a precipitator, it is claimed that a large proportion of the scale formed on the coils flakes off at intervals and drops to the bottom of the heater, whence it may be removed through a handhole. The heating steam is inside the tubes. The water of condensation is trapped to the hot well.

*Berryman's heater* (Fig. 1) employs U-shaped brass tubes for the heating surface. The shell which surrounds the tubes is usually vertical, but a horizontal style is also manufactured, which is probably more convenient for naval use. The steam passes through the tubes. The latter can be cleaned by a steam jet through handholes, or, by removing the flange bolts, the shell may be withdrawn entirely.

*The Wainwright heater* (Figs. 2 and 2*a*) is manufactured in two styles, one having steam inside the tubes and the other having it outside. In the former the tube sheets are dished to give the requisite strength. Straight tubes, spirally corrugated by a patented process, are used and are claimed to give a high efficiency.

In each of the heaters above described there is ample provision for the unequal contraction and expansion of the tubes, thus obviating leaky tube joints.

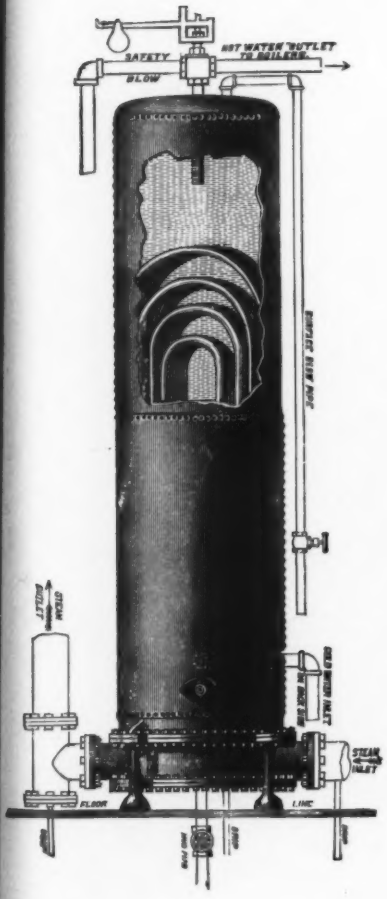



**Fig. 1.**
BERRYMAN'S FEED HEATER.

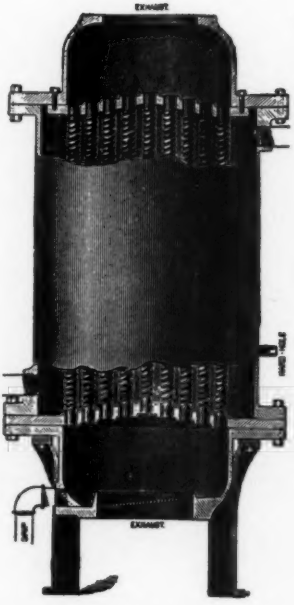



**Fig. 2.**
WAINWRIGHT HEATER.

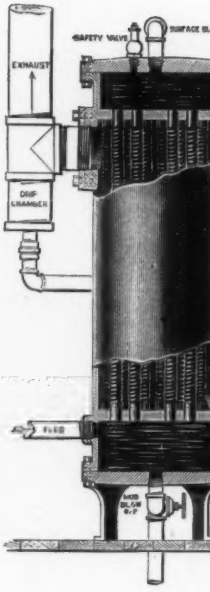



**Fig. 2a.**
WAINWRIGHT H

n.

HEATER.

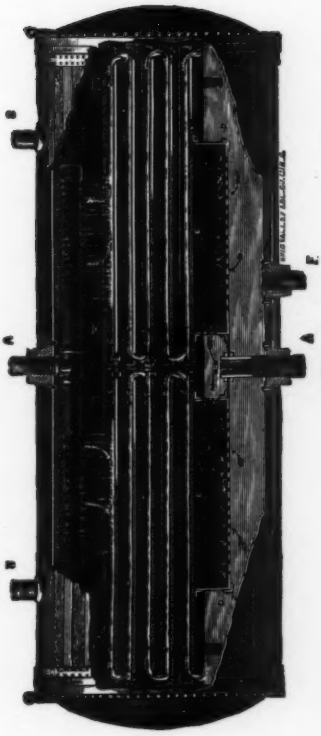


Fig. 4.
STILWELL'S HEATER.

*Fig. 3.*

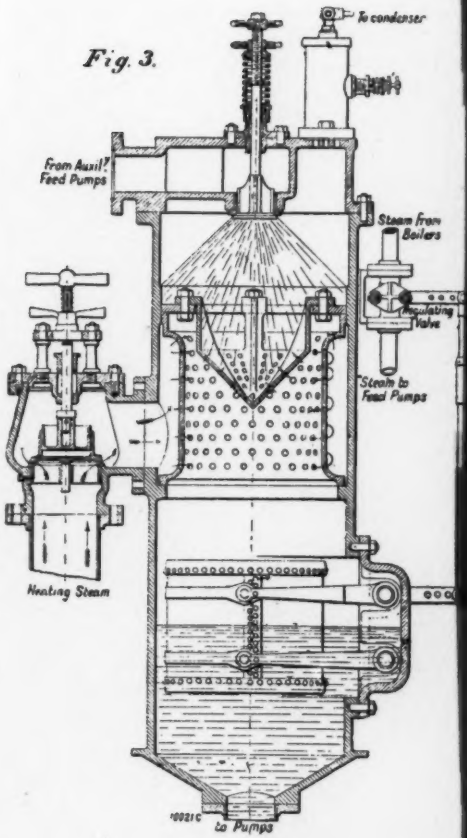



**Fig. 3**
WEIR'S HEATER.

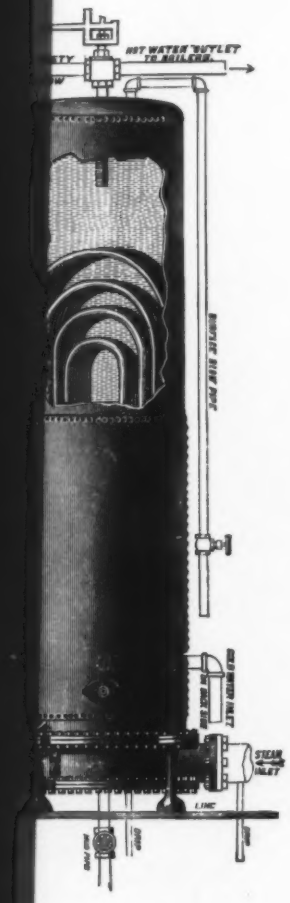



**Fig. 1.**
AN'S FEED HEATER.

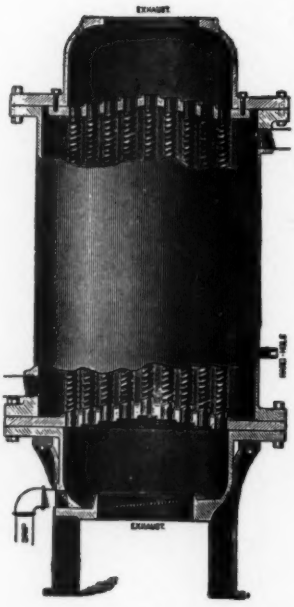



**Fig. 2.**
WAINWRIGHT HEATER.

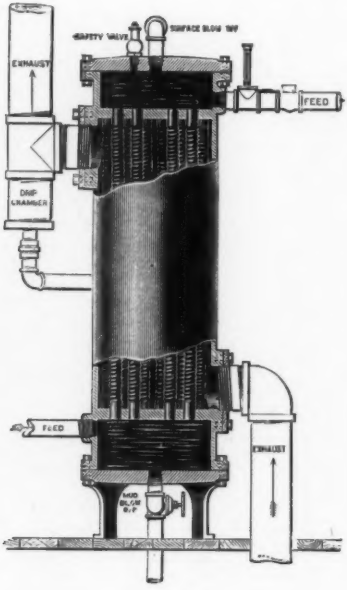



**Fig. 2a.**
WAINWRIGHT HEATER.

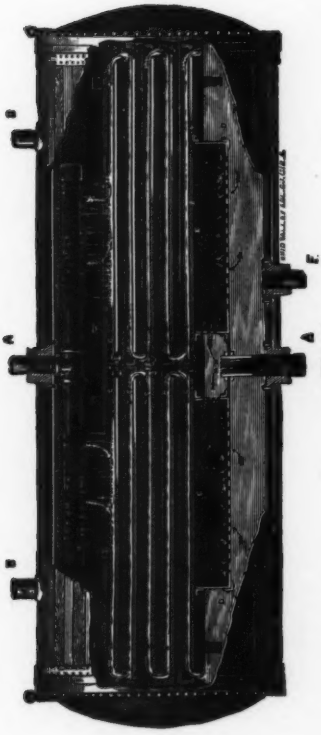


Fig. 4.
STILWELL'S HEATER.

*Fig. 3.*

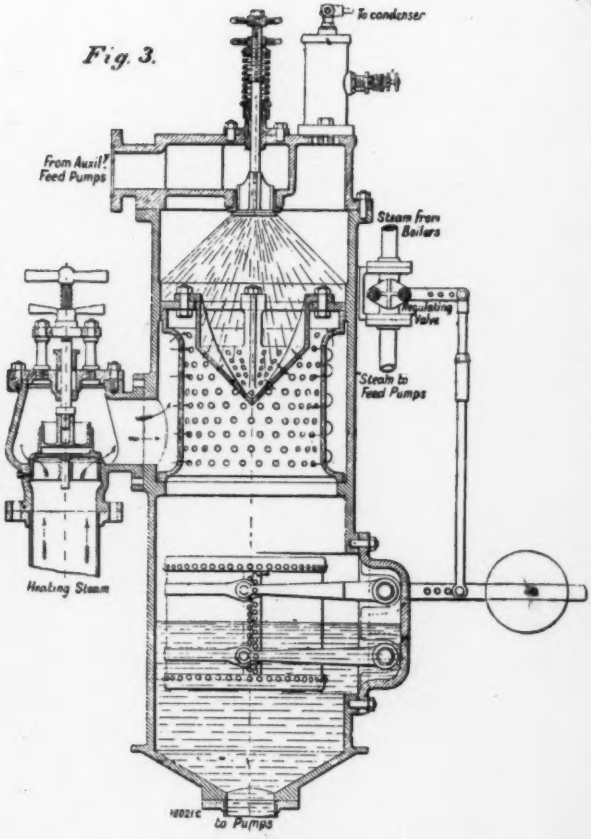



**Fig. 3**
WEIR'S HEATER.

CLASS C.

*Weir's feed heater* (Fig. 3) has had an extensive use at sea. The feed water is sprayed into the steam space of the heater, and is well heated before it passes through a conical perforated diaphragm, which again sprays it into the lower steam space. There is a settling chamber from which any sediment that forms may be periodically blown. The steam enters through a check valve, so that, when steam is taken from one of the engine receivers, there can be no danger of water backing into the receiver. The supply of feed to the boilers is regulated by an internal float, which operates suitable mechanism for actuating the throttle valve of the feed pump.

In heaters of class B, any air that may be separated from the feed water is carried along by the continuous flow of water, or, as in Kirkaldy's heater, is drawn off through a small pipe leading to the hot well. In class C, a small pipe connection must be made to the heating chamber, so that the air can be led off continuously or at intervals. Some manufacturers adopt the practice of operating a small pump or other engine with steam from the heating chamber, the outgoing steam carrying with it sufficient air or other gases to prevent the undue accumulation thereof.

*Stilwell's heater* (Fig. 4) is both a heater and a precipitator, and is therefore provided with pans for catching and retaining the scale forming constituents of the feed water. The feed water is sprayed into the steam space, and then flows from end to end of the pans in thin wide streams, becoming thoroughly heated and purified. A filter is provided at the bottom of the apparatus. The pans are removed by sliding them out when one or both bonnets have been removed. A low power pump is used to withdraw the feed water and deliver same into the boilers, although in shore plants the water can be fed from the heater by gravity alone.

All of the large ships now building for the United States Navy are provided with a couple of auxiliary boilers. The writer believes that it would be good practice to fit such auxiliary boilers with feed heaters of type C. Then it would become possible to

use "salt feed" in these boilers with impunity. The scale is deposited on the precipitator pans, which are very easily scaled. To be sure the water in the auxiliary boilers becomes salt, but that element is easily kept under control by means of the blow valves. When the main boilers need fresh water for "make-up" feed, and when the ship's distillers need steam for conversion into potable water, let the auxiliary boilers supply it all. In fact, the auxiliary boilers can take the place of the usual evaporators—thus dispensing with some very troublesome apparatus and furnishing a fresh water supply with decreased trouble and expense.

For the main boilers heaters of either type B or type C may be used with advantage, although type B would seem preferable in view of the fact that these heaters can be connected up in the feed system without the employment of any additional pumps.

## XVI.

## COMPARISON OF THE PROPELLERS OF SOME UNITED STATES NAVY SHIPS.

By Edwin Griffith, Esq., Associate.

The comparisons made in the accompanying table are based on the data supplied by Passed Assistant Engineer H. Webster, U. S. Navy, in his paper published in the May Journal this year, columns 1 to 13 being reproduced from his table. Column 14 shows the "Admiralty Constants" and gives us an idea of the performance of the ships. The formula in column 15 is often used for comparing disc areas, and is based on the following reasoning:

Let $m$ = a unit mass of the column of water propelled backward,

$A$ = disc area (total),

$v$ = velocity at which the column of water is propelled backward,

$T$ = effective thrust (total),
$I.H.P.$ = indicated horse power (total),
$S$ = speed of ship.

Then, $\text{constant} \times I.H.P. = T \times S$

$$(a) \therefore T = \frac{I.H.P.}{S} \text{ constant.}$$

Now, the resistance of the column of water to motion, and consequently $T$ will vary as $m \times A \times v^2$.

$$\therefore T = A \times v^2 \times \text{constant.}$$

Equating $(a)$ and $(b)$ we get

$$\frac{I.H.P.}{S} \text{ constant} = A \times v^2 \times \text{constant}$$

$$\therefore \text{constant} = \frac{A \times v^2 \times S}{I.H.P.}.$$

If we assume that "$v$" is always a fixed ratio of "$S$," we may substitute $S^2$ for $v^2$ in the formula, which then assumes a practicable form as

$$C = \frac{A \times S^3}{I.H.P.}.$$

It is important to note that this assumption is not correct, as the ratio of "$v$" to "$S$" for maximum efficiency varies in different cases, which accounts largely for the variation in the constants.

The formula used in the last column is original, as far as I know, and is an endeavor to take into account the influence of the velocity of the blade when comparing surface areas, being based on the assumption that as this velocity increases, the surface area may be proportionately decreased. This may not be absolutely correct, but it seems to me much more reasonable than ignoring the speed of blade altogether, as is done in the usual formulæ and methods of comparison. The formula may assume various forms; for instance, some may prefer to take the diameter at the center of pressure, which would be rather more accurate and much more troublesome.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Length of vessel between perpendiculars in feet. | Co-efficient of fineness (prismatic.) | Mean draught on trial in feet. | Displacement at this draught in tons ($D$). | Number of propellers. | Number of blades to each propeller. | Diameter of propeller in feet ($d$). | Mean pitch of propeller in feet. | Helicoidal area of each propeller in square feet. | I.H.P. developed by main engines. | Revolutions of engines per minute ($R$). | Speed of ship in knots per hour ($S$). | Slip of propeller in per cent. of its own speed. | $\frac{S^3 \times D\%}{I.H.P.}$ | $\frac{S^3 \times \text{total disc area}}{I.H.P.}$ | $\frac{S^3 \times R \times d \times \text{total helicoidal area}}{I.H.P. \times 1{,}000}$ |
| *Atlanta* | 270.25 | .547 | 17.0 | 3,085 | 1 | 4 | 17.0 | 24.28 | 96.15 | 2,993 | 72.05 | 15.5 | 10.22 | 260 | 282 | 146 |
| *Baltimore* | 315 | .515 | 19.52 | 4,391.5 | 2 | 3 | 14.5 | 20.0 | 57.17 | 8,698 | 118.05 | 19.57 | 16.01 | 232 | 286 | 169 |
| *Baltimore* | 315 | .515 | 19.87 | 4,500 | 2 | 3 | 14.5 | 21.5 | 57.17 | 9,831 | 116.25 | 19.84 | 19.57 | 216 | 261 | 152 |
| *Bennington* | 208 | .520 | 14 | 1,706 | 2 | 3 | 10.5 | 13.71 | 24.31 | 3,333 | 150.9 | 17.5 | 14.32 | 230 | 278 | 124 |
| *Boston* | 270.25 | .546 | 17.67 | 3,235 | 1 | 4 | 17.0 | 23.67 | 95.67 | 3,855 | 72.2 | 15.58 | 7 62 | 215 | 224 | 115 |
| *Charleston* | 300 | .510 | 17.87 | 3,580 | 2 | 3 | 14.0 | 17.5 | 54.75 | 6,316 | 114.68 | 18.20 | 8.08 | 223 | 294 | 168 |
| *Chicago* | 313 | .551 | 19.0 | 4,543 | 2 | 4 | 15.5 | 24.59 | 77.93 | 4,542 | 70 35 | 15.33 | 10 88 | 217 | 298 | 134 |
| *Concord* | 208 | .520 | 14 01 | 1,707 | 2 | 3 | 10.5 | 13.20 | 26.52 | 3,314 | 152.4 | 17.0 | 14.37 | 212 | 256 | 125 |
| *Cushing* | 138 | .384 | 4.87 | 105.3 | 2 | 4 | 4.25 | 8.42 | 9.30 | 1,754 | 378.12 | 28.48 | 27.3 | 145 | 184 | 190 |
| *Dolphin* | 240 | .501 | 13.79 | 1,413 | 1 | 4 | 13.75 | 24 08 | 70.72 | 2,144 | 74.15 | 15.5 | 12.03 | 219 | 257 | 124 |
| *Newark* | 310.83 | .499 | 18.27 | 3,980 | 2 | 3 | 14.5 | 18.98 | 52.78 | 8,582 | 127.0 | 19.0 | 20.13 | 200 | 264 | 155 |
| *Petrel* | 175 | .490 | 11.21 | 855 | 1 | 3 | 9.75 | 12.25 | 23.6 | 1,051 | 126.78 | 11.79 | 23 07 | 141 | 117 | 45.6 |
| *Philadelphia* | 315 | .515 | 19.21 | 4,375 | 2 | 3 | 14.5 | 20.39 | 57.17 | 8,533 | 119.57 | 19.68 | 18.20 | 237 | 295 | 176 |
| *San Francisco* | 310 | .501 | 18.75 | 4,088 | 2 | 3 | 13.5 | 18.75 | 57.59 | 9,581 | 124.81 | 19.52 | 15.48 | 198 | 222 | 151 |
| *Vesuvius* | 246.25 | .433 | 9 51 | 771 | 2 | 3 | 7.75 | 9.37 | 15.9 | 3,712 | 268.89 | 21.42 | 13.85 | 222 | 248 | 174 |
| *Yorktown* | 208 | .518 | 13.84 | 1,680 | 2 | 3 | 10.5 | 12.5 | 25.42 | 3,416 | 160.8 | 16.65 | 16.06 | 191 | 233 | 116 |

## XVII.

# FORMULÆ FOR PROPORTIONING RIVETED JOINTS AND CALCULATING THE WIDTH AND THICKNESS OF BUTT STRAPS FOR STEEL BOILERS.

By Passed Assistant Engineer F. J. Schell, U. S. Navy.

The formulæ hereafter deduced are given in Traill's work on Boiler Construction, in Appendix D of Seaton's Marine Engineering, edition of 1890, and in Foley's Mechanical Engineer's Reference Book. As no deduction is given in either work, the following solution was made and given to the Engineer Class of '92 at the U. S. Naval Academy, who were thus enabled to use them understandingly, and, it may be mentioned, with considerable success. With the aid of these formulæ the tables for riveted joints in Traill's work are calculated, and for every-day work in the designing room it will undoubtedly be a time-saving operation to obtain the desired information direct from those tables. Where plates of unequal thicknesses are to be joined, however, the formulæ will be found very useful, and it is hoped the method of their deduction will prove of interest to those who like to know the reason for and the method of obtaining tabulated results. For convenience in comparing with the above-mentioned tables the same nomenclature is used. The following assumptions are made: 1st. That the mean tensile strength of the plate is 28 tons and the mean shearing strength of the rivets is 23 tons per square inch of net section; 2d. That rivets in double shear offer 1.75 times the resistance to shearing exerted by rivets in single shear.

Let $p$ = pitch of rivets in inches (greatest).
$d$ = diameter of rivets in inches.
$c$ = a constant whose value is 1 for lap or single-butt strap, and 1.75 for double-butt strapped joints.
$A$ = area of one rivet in square inches.
$n$ = number of rivets in greatest pitch.

$\%_0$ = percentage of plate left between rivets in greatest pitch.

$\%_{0_1}$ = percentage of rivet section as compared with solid plate.

$\%_{0_2}$ = percentage of combined plate and rivet section when alternate rivets are omitted in outer row.

$p_d$ = diagonal pitch.

$E$ = distance from center of rivets to edge of plate.

$V$ = distance between rows of rivets in ordinary zig-zag riveting, and in chain riveting with alternate rivets omitted in outer row.

$V_1$ = distance between outer and next row of rivets in zig-zag riveting with alternate rivets omitted in outer row.

$T$ = thickness of plate in inches.

$T_1$ = thickness of single-butt straps in inches.

$T_2$ = thickness of double-butt straps in inches.

To find the percentage strength of any given joint—

The metal left between rivet holes is $(p - d)\ T$, and the percentage strength of this as compared with the solid plate is $\frac{100\ (p-d)\ T}{p\ T}$, hence $\%_0 = \frac{100\ (p-d)}{d}$ . . . . . (1)

The resistance to shearing offered by the rivets in a single pitch is $23 \times A \times n \times c$; comparing this with the strength of the solid plate ($28\ p\ T$) we have

$$\%_{0_1} = \frac{100 \times 23 \times A \times n \times c}{28 \times p \times T} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

Considering now the case where alternate rivets are omitted in the outer row, in the next row there will remain $(p - 2d)\ T$ solid metal, and $\frac{100\ (p - 2d)}{p}$ will be the percentage strength of this row as compared with the solid plate; but supposing the plate tears along this row of rivets (as shown at K, Fig. 2,) before a total giving way of the joint occurs, one rivet for each pitch must be sheared in the outer row, and the percentage strength of this single rivet is $\frac{\%_{0_1}}{n}$, which value will be obtained from equation (2). From the above considerations we have

$$\%_{0_2} = \frac{100\,(p - 2d)}{p} + \frac{\%_{0_1}}{n}. \quad . \quad . \quad . \quad . \quad . \quad (3)$$

The lowest of the values obtained from equations (1), (2) and (3) is the percentage strength of the joint. An examination of these equations shows that for double butt-strapped joints, so long as the diameter of the rivets is not less than the thickness of the plates $\%_{0_2}$ is always greater than $\%_0$ or $\%_{0_1}$. This is also the case with lap joints so long as the diameter is not less than $\frac{T}{\frac{23}{28} \times .7854} = \frac{T}{.64515}$, and as both these conditions usually hold, the use of formula (3) will seldom be necessary.

---

To find $d$ when $p$, $c$, $n$ and $T$ are given so that $\%_0$ may equal $\%_{0_1}$, (that is, plate and rivet section equivalent in strength).

From (1) and (2) we have

$$\frac{100\,(p - d)}{p} = \frac{100 \times 23 \times A \times n \times c}{28 \times p \times T}. \quad . \quad . \quad (4)$$

Substituting for $A$ its value $\frac{\pi\, d^2}{4}$ and simplifying, we have

$$d^2 + \frac{1.55\,T}{n \times c}\,d = \frac{1.55\,pT}{n \times c}.$$

Solving for $d$ we have

$$d = \sqrt{\left(\frac{.775\,T}{n \times c}\right)^2 + \frac{1.55\,pT}{n \times c}} - \frac{.775\,T}{n \times c},$$

which reduces to

$$d = \sqrt{\frac{.775\,T}{n \times c}\left(\frac{.775\,T}{n \times c} + 2p\right)} - \frac{.775\,T}{n \times c}. \quad . \quad . \quad . \quad (5)$$

If $d$, $c$, $n$ and $T$ are given from equation (4), we have

$$p = \frac{23 \times A \times n \times c}{28 \times T} + d, \quad . \quad . \quad . \quad . \quad . \quad (6)$$

---

To find $d$ and $p$, when $n$, $c$ and $T$ and $\%_0 = \%_{0_1}$ are known—

From (1) we have $p = \frac{100\,d}{100 - \%_0}$. . . . . (7)

Substituting this value of $p$, and for $A$, $\frac{\pi\, d^2}{4} = \frac{22\,d^2}{7 \times 4}$ in (2), we have

$$\frac{100 \times 23 \times 22 \times d^2 \times n \times c}{28 \times 7 \times 4 \times \frac{100\,d}{100 - \%_0} \times T} = \%_{0_1} = \%_0.$$

$$\text{Solving, } d = \frac{1.55 \times \%_0 \times T}{(100 - \%_0) \times n \times c} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

Substituting this value of $d$ in (7), we have

$$p = \frac{100 \times 1.55 \times \%_0 \times T}{(100 - \%_0)^2 \times n \times c} \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

It will generally be found simpler to substitute the numerical value for $d$ found from equation (8) in equation (7), thus obtaining a value for $p$ direct without using equation (9).

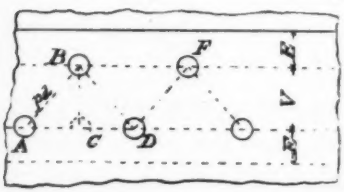
### DIAGONAL PITCHES AND THE WIDTH OF BUTT STRAPS.

The value of the metal in the diagonal pitch $p_d$ is only about $\frac{5}{6}$ of what it is in the horizontal pitch; therefore the net section should be $\frac{1}{5}$ greater than in the horizontal pitch, or in that part of the horizontal pitch to which it is required to be equivalent in strength. In any case the diagonal pitch should not be less than that found by the following formulæ:

I.

Ordinary zig-zag riveting, and chain riveting with alternate rivets omitted in the outer row.

*Fig 1*




Reference to the figure shows that the same reasoning applies to both cases, as in each case the net section of two diagonal pitches must be made equivalent in strength to the net section contained in the greatest horizontal pitch. The liability of the sheet to tear along $AB$ and $BD$ should be the same as along $AD$ or $BF$. Now the metal left along $ABD$ is $2\,(p_d - d)\,T$, and along $AD$ or $BF$ is $(p - d)\,T$; hence $2\,(p_d - d)\,T = \frac{6}{5}\,(p - d)\,T$, and $p_d = \dfrac{6\,p + 4\,d}{10}$. . . . . (10)

From the right angle triangle $ABC$, we have, for the distance between the rows of rivets,

$$V = \sqrt{p_d^2 - \left(\frac{p}{2}\right)^2} = \sqrt{\left(\frac{6p + 4d}{10}\right)^2 - \frac{p^2}{4}} = \sqrt{\frac{11p^2 + 48pd + 16d^2}{100}},$$

$$\text{or } V = \frac{\sqrt{(11p + 4d)(p + 4d)}}{10}, \quad \ldots \quad (11)$$

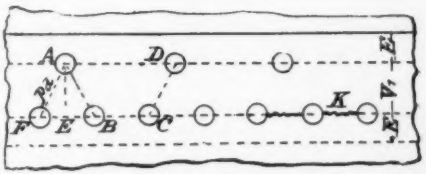
The authors mentioned before state that, for chain riveting, this distance should not be less than $\frac{4d + 1}{2}$, and as this result is greater than that obtained from (11), it is the one that is usually found tabulated.

The distance $E$ from center of rivet to edge of plate should not be less than $1.5\,d$; so that minimum lap of sheets, if lap joint, or half width of butt strap $= 2E + V$. . . . . (12)

## II.

### ZIG-ZAG RIVETING WITH ALTERNATE RIVETS OMITTED IN OUTER ROW.

*Fig. 2.*




An examination of the figure shows that rupture may occur by the plate giving away along $ABCD$ or along $AD$, and to make the joint symmetrical in strength, the net section along $ABCD$ must be equivalent in strength to the net section along $AD$. Now $BC = \frac{p}{2}$, and the net section on $BC$ is $\left(\frac{p}{2} - d\right) T$, while on $AD$ it is $(p - d)\,T$: hence the section to which the metal left on the lines $AB$ and $CD$ must be equivalent in strength is $(p - d)\,T - \left(\frac{p}{2} - d\right) T = \frac{p}{2} T$, but net section on $AB$ or $CD$ is $(p_d - d)\,T$; therefore, $2\,(p_d - d)\,T = \frac{6}{5}\left(\frac{p}{2} T\right)$ and $p_d = .3\,p + d$. . . . . (13)

In the triangle $AFE$ we have $FE = \frac{BF}{2} = \frac{p}{4}$, and for the distance between the rows of rivets we have

$$V_1 = \sqrt{\left(\frac{3p + 10d}{10}\right)^2 - \left(\frac{p}{4}\right)^2} = \sqrt{\frac{9p^2 + 60pd + 100d^2}{100} - \frac{p^2}{16}}$$

$$= \sqrt{\frac{11p^2 + 240pd + 400d^2}{400}} = \frac{\sqrt{(11p + 20d)(p + 20d)}}{20}. \quad (14)$$

As before, the half breadth of butt strap $= 2E + V_1$. . . (15)

As the riveting in all ordinary cases is either of the form shown in Fig. 1 or Fig. 2, or a combination of those forms, equations (10), (11), (12), (13) and (14) have a general application. For instance, consider the case of a double-butt strapped, treble-riveted zig-zag joint, with alternate rivets omitted in the outer row; the distance $V_1$, between the outer and second row is obtained from equation (14); the distance $V$ is obtained from equation (11).

In this case, half breadth of butt strap $= 2E + V_1 + V$. (16)

### THICKNESS OF BUTT STRAPS.

From considerations of strength and to secure tight joints, the aggregate thickness of the butt straps should always be more than that of the plate. For single-butt straps $T_1 = \frac{9}{8}T$, and, for double straps $T_2 = \frac{5}{8}T$, are arbitrarily taken as the minimum values allowed.

When alternate rivets are omitted in the outer row, the thickness obtained above must be increased; the ratio of this increase is expressed by $\frac{(p-d)}{(p-2d)}$, which is the ratio of the net section left in outer row to the net section left in the next row. With this form of riveting, the minimum values of $T_1$ and $T_2$ will be found from the following equations, viz.:

$$T_1 = \frac{9}{8}\left(\frac{p-d}{p-2d}\right)T, \quad T_2 = \frac{5}{8}\left(\frac{p-d}{p-2d}\right)T.$$

## XVIII.

# TRIAL OF THE PADDLE STEAMER *VILLE DE DOUVRES.*

By Professor Alex. B. W. Kennedy.

[A report of the Research Committee on Marine Engine Trials of the Institution of Mechanical Engineers. Read at the spring meeting of 1892.]

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Since their report of April, 1891, the Research Committee on Marine Engine Trials have been enabled, through the kindness of the Belgian Government, to carry out a trial on a large paddle steamer, which in many respects differs considerably from the vessels tested previously.

*Steamer.*—The steamer tested was the *Ville de Douvres*, a paddle steamer owned by the Belgian Government, and employed by them on the postal service between Ostend and Dover. The committee are very deeply indebted to the Government and to the officers of their Service du Génie Maritime, especially to M. Allo, directeur général de la marine; M. Delcourt, ingénieur-en-chef, directeur, and M. Lecointe, ingénieur de première classe; also to M. Kraft, ingénieur-en-chef, and M. Ortmans, ingénieur, of the Société Cockerill; for the many facilities which they afforded throughout for carrying on the trial, and for the arrangements they kindly made for the accommodation and comfort of all on board. The committee have also to thank Professor Boulvin, of Ghent University, for the trouble he took in obtaining permission from the Belgian Government to test one of their steamers, and for the assistance he rendered during the trial, which originated in a conversation between Professor Boulvin and Mr. Donkin at Ghent.

The *Ville de Douvres*, which is driven by feathering paddles, was built and engined by the Société Cockerill, Seraing, Belgium, and was delivered by them to the Belgian Government in February, 1890. Between that time and the date of the trial she

made 220 voyages from Ostend to Dover and back. She is a vessel of 271 ft. length between perpendiculars, 29 ft. breadth, and 15.5 ft. depth moulded. Her registered tonnage is—gross 855 tons, under deck 776 tons, and net 495 tons. Her draught during the trial was 8 ft. 6½ in. forward, and 9 ft. 7 in. aft, or 9 ft. 0¾ in. mean; corresponding to a displacement of 1,090 tons.

The trial was made on Tuesday, 8th September, 1891, upon a run from Ostend over a course round the three light vessels *Nord-Hinder*, *Outer-Gabbard* and *Corton*, in the North Sea. Previous to the trial the vessel had been lying in Ostend harbor, where her machinery had been overhauled. She left her moorings about half-past seven o'clock on the morning of the 8th September, and observations were begun to be taken at 8 A. M., but, owing to various causes, the trial was not started until 10 A. M. It was continued until 7 P. M., on the same day, thus lasting for nine hours. The quantity of fuel burnt and other conditions did not allow of its further prolongation. The weather was fine throughout, with smooth sea, so that no difficulty was experienced in taking any of the usual observations. The speed of the engines was fairly constant throughout the trial, with the exception of a period of fourteen minutes from 1.10 to 1.24 P. M., when the engines slowed down a little, owing to temporary failure of the centrifugal circulating pump, and consequent loss of vacuum in the condenser. The reading of the counter was noted several times during this period, in addition to the readings taken in ordinary course. The valve gear remained unaltered throughout the trial.

*Engines.*—The *Ville de Douvres* is fitted with compound inclined surface-condensing engines, working on two cranks at right angles, the high-pressure crank leading. The high-pressure cylinder is situated on the port side of the vessel. The diameters of the cylinders are 50.12 in. and 97.12 in., by gauges. The piston rods are both 8.27 in. diameter, and there are no tail rods. The stroke of both cylinders is 72 in. Neither of the cylinders is specially jacketed; the intermediate receiver encircles the high-pressure cylinder. The clearance volumes of the cylinders as given by the makers are, high pressure 15 per

cent., and low pressure 12 per cent., of the volumes swept through by their respective pistons.

The high-pressure cylinder is provided with a pair of piston valves, and the low-pressure cylinder with a single one. The valve gear is the Allan link motion with a variable cut-off of from 50 to 75 per cent. of the stroke. There are two feed pumps, two air pumps and two bilge pumps, all vertical and single acting, one of each driven from each of the two crossheads by bell-crank levers; and there is one centrifugal circulating pump, driven by a separate double-acting vertical engine, taking steam from the main boilers and exhausting into the condenser. The feed pumps and bilge pumps are all 6.69 in. diameter, and the air pumps are each 32.68 in. diameter. The stroke of all these six pumps is 24.61 in. The circulating pump is 2 ft. 10 in. diameter over the blades, and the suction and delivery pipes are each 14.2 in. bore. The circulating-pump engine has one cylinder, 10 in. diameter and 10 in. stroke.* The donkey pump takes steam from the main boilers, and exhausts through a three-way cock either into the atmosphere or into the condenser. During the fourteen minutes when, owing to the failure of the circulating pump, the donkey pump was in use during the trial, it was made to exhaust into the condenser. The surface condenser contains 6,540 square feet of tube surface, in 6,026 brass tubes of 0.79 in. external diameter and 5 ft. 3 in. length between tube-plates. There are four tube-plates, the tubes being arranged in two sets; and the circulating water is divided between them by means of deflecting plates. In this way the circulating water is made to pass three times through the condenser, entering at the top so that the coldest water meets the hottest steam. There is no feed heater. The base of the condenser is 13 in. above the foot-valve of the air-pump, and 3.15 in. above the upper surface of the air-pump piston when at the bottom of its stroke. The bottom edge of the aperture by which the water escapes from the hot well is 17.7 in. above the upper surface of the air-pump piston when at the top of its stroke.

* With an estimated mean effective pressure of 50 lbs. per square inch in the cylinder, and at 240 revolutions per minute, which was its mean speed throughout the trial, the circulating-pump engine would develop about 47 I.H.P.

*Paddle wheels.*—The two paddle wheels are fitted with feathering floats of curved steel. Their diameters are 22 ft. 10 in. over the floats, and 14 ft. 2 in. inside the floats, so that their mean diameter is 18 ft. 6 in. In each wheel there are nine floats, each 10 ft. broad and 4 ft. 4 in. deep, pivoted round a circle of 19 ft. 2 in. diameter. When the vessel has a mean draught of 9 ft. 0¾ in., which was her mean draught during the trial, the maximum immersion of the inner edges of the submerged floats is about 17 in., or one-third of the depth of the floats.

*Boilers.*—Steam is supplied by four single-ended boilers, designed for a working pressure of about 118 lbs. per square inch above the atmosphere. The furnaces, combustion chambers, tube plates, and lower portions of the fronts of the boilers are of iron, and the remainder is of Siemens-Martin's steel. The boilers are 13 ft. mean diameter and 10 ft. long, with three plain furnaces in each, or 12 furnaces in all. The total grate area is 236 square feet, each grate being 6 ft. 6¾ in. long and 3 ft. broad. There are 66 wrought-iron fire-bars of the ordinary type in each fire, arranged in three sets of 22 each. The total heating surface in the four boilers is 7,340 square feet, of which 6,280 square feet is tube surface. The total heating surface is therefore 31.1 times, and the tube surface 26.6 times the grate area. There are in all 1,356 tubes, of which 312 are stay tubes. The tubes are all 2.48 in. external diameter, and 7 ft. 1⅝ in. long between plates, their length being, therefore, 34.5 times their external diameter. The internal diameter of the ordinary tubes is 2.24 in., and of the stay-tubes 1.93 in. There are two funnels, one for each stokehold; their internal diameter is 5 ft. 3 in., and the total height of each is 49 ft. 8 in. above the center of the lowest furnaces. The total cross-sectional area through the tubes is 35.0 square feet, and the total area across the two funnels is 43.3 square feet. The net volume of the boilers is 6,210 cubic feet.

The boilers are worked under forced draft on the closed stokehold system. The two stokeholds are situated one forward and one aft of the engine room, and communicate with it by air locks. On the stokehold side of each of the two bulkheads

which separate the stokeholds from the engine room is placed a centrifugal fan, 60 in. diameter and 20¼ in. wide, driven direct by a three-cylinder Brotherhood engine in the engine room; these maintain an air pressure equivalent to from 0.7 to 1.0 in. of water in the stokeholds. The two fan engines have each three cylinders, 5 in. diameter and 5 in. stroke.* They are supplied with steam from the main boilers and can be exhausted into the atmosphere, the receiver or the condenser; during the trial they both exhausted into the atmosphere. The effect of this arrangement of forced draft with the block fuel used during trial was in this case to fill the whole atmosphere in the stokehold with a fine dust, the blocks being broken up with hammers instead of being cut with hatchets.

*Weights.*—The total weight of the engines and boilers and all mountings, including water in condenser pipes and boilers, is about 361 tons, exclusive of the two paddle wheels. The following are the weights of the various parts of the machinery, boilers and accessories, as given by the makers:

| | Tons. |
|---|---|
| Main engines alone, | 145.27 |
| Paddle wheels, | 45.21 |
| Circulating pump, | 2.20 |
| Donkey pump, | 1.74 |
| Pipes, valves, &c., | 10.37 |
| Water in condenser, pipes and pumps, | 7.85 |
| Boilers, &c., | 132.35 |
| Water in boilers, | 61.51 |
| Total, | 406.50 |

*Duration of Trial.*—The duration of the trial from start to finish was exactly 9 hours, or 540 minutes.

*Fuel Measurement.*—Block fuel was used throughout the trial. It had been hoped that the total quantity of fuel used might be arrived at by counting the blocks and weighing only a propor-

* Mr. Brotherhood states that each of these fan engines would develop about 14 I.H.P. at a speed of 404 revolutions per minute, which was the mean speed during the trial. The corresponding mean effective pressure in the cylinders would be about 47 lbs. per square inch.

tion of them; but they were found to vary so much in size and weight that this was impossible, and the whole of the fuel used throughout the trial was weighed in baskets by means of spring balances in the stokeholds, as in the former trials. About 150 lbs. at a time was put down on the floor beside each boiler. The trial was started with clean floors, and as far as possible, the time of first stoking from each weighed lot of fuel was noted, as well as the time when the whole of the weighed fuel was finished. Owing to the rapidity with which the firing had occasionally to be carried on, it was not always found possible to note these times, the whole attention of the observers being sometimes devoted to the weighing and registering of the quantity of fuel used and to seeing that no unweighed fuel was thrown on the fires. Therefore, although the total quantity of fuel used during the trial, as well as the quantity used by each of the four boilers, may be taken as correct within the ordinary limits of error, the intermediate points on the line of coal consumption cannot be vouched for to the same degree of accuracy.

The fires were cleaned once during the trial, and the clinker and ashes were measured after the trial was over, the total amount being 2,367 lbs. in the forward stokehold and 2,393 lbs. in the after stokehold, or a total of 4,760 lbs. in all, which is about 7.2 per cent. of the whole fuel used.

The block fuel used throughout the trial was from the manufactories of M. Dehaynin, of Marcinelle, and M. Henin, of Chatelineau. Samples were taken from the weighed lots of fuel frequently during the trial; and after a thorough mixture of all these samples, the final analyses, which have again been kindly made by Mr. C. J. Wilson, are as follows:

| | Fuel as used. | Dry fuel. |
|---|---|---|
| Carbon, | 84.65 per cent. | 86.74 per cent. |
| Hydrogen, | 3.98 " " | 4.08 " " |
| Moisture, | 2.41 " " | 0.00 " " |
| Ash, | 5.30 " " | 5.43 " " |
| Nitrogen, sulphur, oxygen, &c., by difference, | 3.66 " " | 3.75 " " |
| | 100.00 | 100.00 |

A sample of the ash was also collected, and has been analyzed by Mr. Wilson, as follows:

| | |
|---|---|
| Loss on ignition (= carbon), . | 42.86 per cent. |
| Mineral matter, . . | 57.14 " " |
| | 100.00 |

The calculated calorific value of the fuel is 14,390 thermal units per lb., which corresponds with the evaporation of 14.90 lbs. of water from and at 212° Fahr., and to an equivalent carbon value of 0.99 lb. per lb. of fuel. The total fuel used was as follows:

| | |
|---|---|
| After stokehold, port side, . . | 15,583 lbs. |
| After stokehold, starboard side, . | 16,742 " |
| Forward stokehold, port side, . . | 16,737 " |
| Forward stokehold, starboard side, . | 17,358 " |
| | 66,420 " |

This amounts to 123 lbs. per minute, or 7,380 lbs. per hour.

*Furnace Gases.*—Eighteen samples of the furnace gases were obtained, a sample from each funnel being collected over mercury by Mr. Wilson each hour as the trial went on. The analyses of these samples are given in the annexed tables, the samples collected from each funnel being grouped together and their mean analyses given separately, as was done in the case of the S.S. *Colchester*, which also was provided with a pair of funnels. The mean analyses for both funnels are also given, and these have been used in calculating the heat account and the quantity of air required for combustion. In the present instance the volumetric analysis of each sample was not determined separately, but in several cases three or four samples from the same funnel were mixed together in equal volumes, and the analysis of each of these mixtures was determined, as indicated in the annexed tables. Allowance has been made for this in calculating the mean analyses for each funnel, and for both.

Two mercury thermometers of the same description as those used in former trials were employed to read the temperatures of

the gases in the two chimneys. Both of these thermometers read up to 860° Fahr.; but unfortunately it was found that in every case, with the exception of four, the temperature considerably exceeded the maximum possible reading of the thermometer. The mean temperature in the two chimneys is therefore

*VILLE DE DOUVRES* TRIAL.

*Analyses of Funnel Gases by* Volume.

| | No. of Sample. | Carbonic Acid. | Carbonic Oxide. | Oxygen. | Nitrogen. |
|---|---|---|---|---|---|
| | | Per cent. | Per cent. | Per cent. | Per cent. |
| FORWARD FUNNEL. | 2 | 9.99 | 0.00 | 9.52 | 80.49 |
| | 4 | 10.19 | 0.00 | 9.22 | 80.59 |
| | 6, 8, 10 * | 12.66 | 0.00 | 6.69 | 80.65 |
| | 12, 14, 16, 18 * | 9.78 | 0.00 | 9.92 | 80.30 |
| | Mean, | 10.81 | 0.00 | 8.72 | 80.47 |
| AFTER FUNNEL. | 1 | 12.61 | 0.00 | 6.58 | 80.81 |
| | 3 | 14.06 | 0.00 | 5.23 | 80.71 |
| | 5, 7, 9 * | 12.21 | 0.00 | 7.32 | 80 47 |
| | 11, 13, 15, 17 * | 11.84, | 0.00 | 7.72 | 80.44 |
| | Mean, | 12.30 | 0.00 | 7.18 | 80.52 |
| Mean of Both Funnels, | | 11.55 | 0 00 | 7.95 | 80.50 |

unknown; but from observations made of the motion of the mercury as it approached the end of the thermometer tube, it has been thought proper for the purpose of working out the heat account to assume that an excess of 50° Fahr. above the maximum possible reading of the thermometer may be taken as representing this temperature within reasonable limits of accuracy. For the purposes of the calculations which follow, 910° Fahr. is therefore assumed to be the mean temperature of the chimney gases. The mean air temperature on deck was 64° Fahr.

The mean vacuum in the chimneys was measured by a U-gauge in each funnel, each of which gave a mean reading of 0.22 inch of water. The mean chimney draft during the trial corresponded, therefore, with a pressure of from 0.92 to 1.22 inch of water.

*VILLE DE DOUVRES* TRIAL.

*Analyses of Funnel Gases by* Weight.

| No. of Sample. | Carbonic Acid. | Carbonic Oxide. | Oxygen. | Nitrogen. | Time of Collecting. |
|---|---|---|---|---|---|
| | Per cent. | Per cent. | Per cent. | Per cent. | |
| 2 | 14.66 | 0.00 | 10.16 | 75.18 | 10.45 a.m. |
| 4 | 14.95 | 0.00 | 9.83 | 75.22 | 11.45 " |
| 6 | | | | | 12.45 p.m. |
| 8 * | 18.39 | 0.00 | 7.07 | 74.54 | 1.45 " |
| 10 | | | | | 2.45 " |
| 12 | | | | | 3.45 " |
| 14 * | 14.36 | 0.00 | 10.60 | 75.04 | 4.45 " |
| 16 | | | | | 5.45 " |
| 18 | | | | | 6.45 " |
| Mean, | 15.80 | 0.00 | 9.29 | 74.91 | |
| 1 | 18.32 | 0.00 | 6.95 | 74.73 | 10.15 a.m. |
| 3 | 20.31 | 0.00 | 5.49 | 74.20 | 11.15 " |
| 5 | | | | | 12.10 p.m. |
| 7 * | 17.76 | 0.00 | 7.74 | 74.50 | 1.20 " |
| 9 | | | | | 2.15 " |
| 11 | | | | | 3.15 " |
| 13 * | 17.25 | 0.00 | 8.18 | 74.57 | 4.15 " |
| 15 | | | | | 5.15 " |
| 17 | | | | | 6.15 " |
| Mean, | 17.88 | 0.00 | 7.60 | 74.52 | |
| Mean of Both Funnels, | 16.84 | 0.00 | 8.44 | 74.72 | |

* Mixed in equal volumes, and the mean analysis taken.

*Feed-Water Measurement.*—Owing to the large quantity of water required by the engines (over 1,100 lbs. per minute), it was found impracticable to measure the feed in tanks, as in former trials, and it was ultimately decided to employ water meters for this purpose. The meters used were two 4-inch Kennedy's positive piston water meters, kindly lent to the committee by the makers, the Kennedy's Water Meter Co., Kilmarnock, by whom

they were specially constructed for use on this trial. The committee are greatly indebted to the company and to their managing director, Mr. Thomas Kennedy, for the generous way in which they volunteered to provide the meters and their fittings for use on the trial. The two meters, each of which was capable of measuring 32,000 gallons per hour, were placed between the feed pumps and the boilers, and were arranged in parallel circuit on a two-branch pipe fitted with stop cocks, so that the whole of the feed water could be made to pass through either of the meters, or could be divided between the two. Only one of the meters, however, was in use during the trial, as it was found to do its work admirably and to require very little care or attention on the part of the observers. The meters were tested at Kilmarnock before the trial under different conditions and at various speeds, and were found to give an average excess reading amounting to three-quarters of one per cent., which has been allowed for in the totals. After the trial was over, the meter which had been used to measure the feed water was again tested, and its correction was found not to differ sensibly from that obtained during the tests made before the trial. The whole of the steam used by the main engines and all the auxiliary engines is supplied by the main boilers, so that the feed water for all these engines passed through the meter, and is included in the totals.

The reading of the meter index was noted every quarter of an hour throughout the trial. The total amount of water used by all the engines was 595,620 lbs., during a total time of 9 hours, or 540 minutes. This is equivalent to 66,180 lbs. per hour, or 1,103 lbs. per minute.

Both at the beginning and at the end of the trial the boiler pressure was rising, but the water level in the boilers averaged 2.82 in. lower at the finish than at the commencement. This corresponds with a total of 6,220 lbs. of water, or a little over one per cent. of the total feed; this amount has been included in the figures given above. It may be of interest to note that an error of one inch in reading the level of one of the boilers, which is certainly a greater error than could have occurred, would make

a difference of only about 550 lbs., or less than 0.1 per cent. of the total feed water.

The temperatures of the circulating water and of the discharge water were measured at about half-hourly intervals throughout the trial. Calculating from these observations, the mean temperature of the circulating water was 61.7° Fahr., and of the discharge water 85.0° Fahr.

*Feed Water to Auxiliary Engines.*—Separate runs of the auxiliary engines, to determine the quantity of feed water used by them individually, were made on 9th September, the day following the trial. Each of these runs lasted for two hours, and from the results obtained the feed water used by the auxiliary engines throughout the trial has been computed. In each run the speed of the auxiliary engine and the boiler pressure were maintained as far as possible the same as during the trial. No water was supplied to the boilers during the run, the water level in the boilers being allowed to fall gradually; and at the end of two hours the engine was stopped, and a sufficient quantity of water pumped through the meter into the boilers to raise the water level in them just to the position in which it stood at the commencement of the run. This measured quantity of water has been taken to represent with sufficient accuracy the consumption of the engine during its two hours' run.

The water used by one of the two three-cylinder Brotherhood engines driving the fans was found to be 2,120 lbs. in the two hours' run, at a mean speed of 376 revolutions per minute. Correcting for the mean speed of these engines during the trial, namely, 404 revolutions per minute, this is equivalent to 1,140 lbs. per hour for each fan engine, or 20,520 lbs. for both during the nine hours' trial.

The circulating-pump engine consumed 4,140 lbs. of feed water at a mean speed of 240 revolutions per minute, which was also the mean speed during the trial. This is equivalent to 2,070 lbs. per hour, or 18,630 lbs during the nine hours' trial.

On the assumption that these figures hold good for the nine hours' trial, the total feed water used by the three auxiliary engines during the trial was 39,150 lbs., which is 6.57 per cent. of

the whole feed water consumed. The following table shows the relative consumption of feed water by the main engines and by the three auxiliary engines on this assumption:

| Feed-water Consumption. | Total. | By Main Engines. | By Auxiliary Engines. |
|---|---|---|---|
| | Lbs. | Lbs. | Lbs. |
| Throughout trial (9 hours), . | 595,620 | 556,470 | 39,150 |
| Per hour, . . . . | 66,180 | 61,830 | 4,350 |
| Per minute, . . . . | 1,103 | 1,030.6 | 72.5 |
| Per revolution of main shaft, . | 29.96 | 27.99 | 1.97 |

It was found impossible to arrange for the separate measurement of the auxiliary feed water. All that was used passed through the meter, and is included in the totals given above.

*Priming Water Tests.*—Three times, at about equal intervals during the trial, samples of the boiler water were taken, and at the same time quantities of steam from the main steam pipe were collected and condensed. These samples were afterwards analyzed by Mr. Wilson to determine the quantity of salt present in each, and gave the following results:

| Sample. | Salt present. |
|---|---|
| No. 1 from boilers | 88.8 grains per gallon. |
| No. 2 " " | 115.3 " " " |
| No. 3 " " | 113.0 " " " |
| No. 1 " steam pipe, No. 2 " " , No. 3 " " | All contained less than 0.16 grain of salt per gallon. |

These analyses show that in every one of the three cases the condensed steam contained considerably less than one-fifth of one per cent. of the boiler water, or that there was practically no priming during the trial.

The method of employing this test for the purpose of ascertaining the amount of priming at any given time is as follows: A quantity of steam from the main steam pipe is condensed in a special surface-condensing apparatus, and collected, and at the same time a sample of water is taken separately from the boilers. Both of these samples are carefully analyzed to determine the

quantity of salt present in each. As the whole of the salt found in the sample from the steam pipe must have come over from the boiler in conjunction with priming water, and not with steam, a simple calculation will show how much boiler water corresponds with the quantity of salt, if any, found in the steam pipe sample. From this it is easy to determine what percentage of the whole feed water has passed from the boilers in the form of water, or in other words, what percentage there is of priming. The chemical determination for salt is a very simple one, and is capable of being carried with ease to an exceptional degree of certainty.

In order to test the accuracy of the above method, Mr. Wilson took a measured quantity of each sample of boiler water, and after mixing it with a measured quantity of the corresponding sample of condensed water from the steam pipe, he determined, both by analyses of the mixture and by calculation from the quantities taken, the apparent priming shown by each of the mixtures. The following table gives the result of these experiments:

| No. of Mixture. | Apparent Priming. | | Difference between Analyzed and Calculated Percentages. |
|---|---|---|---|
| | by Analysis. | by Calculation. | |
| | Per cent. | Per cent. | |
| No. 1 | 0.92 | 0.85 | 0.07 |
| No. 2 | 0.86 | 0.85 | 0.01 |
| No. 3 | 1.30 | 1.24 | 0.06 |

These last experiments show that the actual method of testing for priming water may be taken as giving results correct to within eight per cent. of the real amount of priming, although the latter did not itself exceed 1.3 per cent. It will be observed that in every one of the three cases, actual analysis gave a somewhat higher result than that calculated from the quantities in the mixture.

A considerable amount of water came through the indicator cocks on both cylinders during the trial. This fact, taken in conjunction with the results of the priming tests given above, shows

that water appearing at the indicator cocks, even although in considerable quantities, is no criterion as to priming.

*Power Measurements.*—Indicator diagrams were taken at half-hourly intervals throughout the greater part of the trial; but towards the end the number was increased by their being taken at intervals of a quarter of an hour. In this way 21 sets of diagrams, or 84 single diagrams, were taken in all. Owing to temporary failure of two of the indicators, however, a few of these diagrams were found to be imperfect and were accordingly rejected, the total number of diagrams available for purposes of calculation being thereby reduced to 78. The indicators used were all of the Richards type, made by the Crosby Steam Gage and Valve Co., and kindly lent to the committee by the makers for use on the trial. The high-pressure diagrams were taken with springs having a scale of 60 lbs., per inch, and the low-pressure diagrams with springs of 20 lbs. per inch. The following are the mean effective pressures in the two cylinders in lbs. per square inch:

| Cylinder. | Front. | Back. | Mean. |
|---|---|---|---|
| High-pressure, . . | 57.90 | 53.08 | 55.49 |
| Low-pressure, . . | 15.63 | 15.45 | 15.54 |

These pressures correspond with the following I.H.P.'s:

| | |
|---|---|
| High-pressure cylinder, . . . . . | 1,444 |
| Low-pressure cylinder, . . . . . | 1,533 |
| Total I.H.P., . . . . . | 2,977 |

The maximum I.H.P. given by any one set of diagrams was 3,229, which occurred at 2.30 P. M., with 37.0 revolutions per minute, and boiler pressure of 108.8 lbs. per square inch. The minimum I.H.P. by any one set of diagrams when not slowed down was 2,757 at 6.45 P. M., with 36.6 revolutions per minute, and boiler pressure of 97.3 lbs. per square inch. The set of diagrams nearest to the mean was taken at 5.45 P. M., with 37.7 revolutions per minute, and boiler pressure of 100.8 lbs. per square inch. From the 78 diagrams which were taken during the trial a mean diagram has been plotted for each of the two cylinders.

If to the total I.H.P. of the main engines, given above, were added the estimated I.H.P.'s of the three auxiliary engines in use during the trial, the mean total I.H.P. of the main engines and the three auxiliary engines during the trial would be roughly about 3,050.

*Speed.*—The counter was read every half hour throughout the greater part of the trial, and every quarter of an hour towards the end, alternately with the times for taking indicator diagrams. The total number of revolutions made was 19,885 in 9 hours, giving an average speed of 36.82 revolutions per minute throughout the trial. The maximum number of revolutions per minute for any half hour during the trial was 38.1, and the minimum, except during the time when slowed down, was 36.4 revolutions. The mean speed for the fourteen minutes from 1.10 to 1.24 P. M., when the engines slowed down owing to failure of the vacuum, was 20.2 revolutions per minute.

*Pressures.*—As in the *Iona* trial, a standard gauge was used to check the pressure gauges, and a correction was made where necessary. The mean barometric pressure during the trial was 30.21 inches of mercury, or 14.84 lbs. per square inch. The mean boiler pressure was 105.8 lbs. per square inch above the atmosphere by the four pressure gauges on the boilers. The mean pressures in the high-pressure valve chest and the intermediate receiver were respectively 99.4 and 12.0 lbs. per square inch above the atmosphere. The mean vacuum in the condenser was 20.6 inches of mercury by gauge, which corresponds with a mean absolute back pressure in the condenser of 4.72 lbs. per square inch. The mean initial pressure in the high-pressure cylinder, as measured from the diagrams, was 93.2 lbs. per square inch above the atmosphere; and the mean pressure during admission, obtained in the same way, was 89.2 lbs. per square inch above the atmosphere. The mean vacuum in the low pressure cylinder, as measured from the diagrams, was 8.78 lbs. per square inch below the atmosphere, which corresponds with a mean absolute back pressure of 6.06 lbs. per square inch in the cylinder. The poor vacuum thus indicated was the subject of considerable discussion before the commencement of

the trial; and it was then understood that this was the vacuum commonly obtained when the engines were working at full power.

*Boiler Efficiencies.*—The mean rate of combustion in the furnaces was 31.3 lbs. of fuel per square foot of grate area per hour, or 1.01 lbs. per square foot of total heating surface per hour. The total amount of feed water pumped into the boilers was at the rate of 8.97 lbs. per lb. of fuel. The average temperature of the feed water throughout the trial was 158° Fahr., and the temperature corresponding with the mean boiler pressure was 342° Fahr., so that each pound of steam must have taken up 1,060 thermal units. The equivalent evaporation from and at 212° Fahr., was therefore 9.84 lbs. of water per lb. of fuel, or 9.94 lbs. per lb. of carbon value in the fuel. The equivalent amount of heat utilized per lb. of fuel was 9,509 thermal units, or 66.1 per cent. of the whole thermal value of the fuel. This percentage therefore represents the actual boiler efficiency.

The total calculated calorific value of the fuel burnt per minute was 1,770,000 thermal units.

The weight of dry air per lb. of fuel, calculated from the series of analyses of chimney gases given in Table 13, works out to 17.9 lbs.; so that the total weight of furnace gases per lb. of fuel would be about 18.8 lbs. Assuming the estimate of the mean chimney temperature to be correct, as given in a former paragraph, these gases were raised in temperature from 64° Fahr., the temperature of the outer air, to 910° Fahr., the estimated mean chimney temperature. Taking the mean specific heat of the gases as 0.243, this corresponds with a loss of 3,853 thermal units per lb. of fuel, or 26.8 per cent. of the whole thermal value of the fuel. In estimating the weight and specific heat of the chimney gases, it has been assumed that the whole of the hydrogen in the fuel was burnt. This assumption may not be absolutely correct, but the error due to it is exceedingly small. The loss due to the evaporation of the moisture in the fuel was so small that it may be neglected; and none of the eighteen gas samples collected during the trial was found on analysis to contain carbonic oxide. The two percentages mentioned above,

66.1 and 26.8, add up to 92.9 per cent., so that the quantity of heat unaccounted for was 7.1 per cent. of the whole thermal value of the fuel. This is mainly covered by radiation, but would also include any losses due to unburnt carbon passing up the chimney, imperfect combustion of the hydro-carbons, and other causes.

The weight of air theoretically necessary for the combustion of 1 lb. of the fuel is 11.1 lbs. The air actually used, 17.9 lbs. per lb. of fuel, is therefore about 1.6 times the amount theoretically required.

The weight of water evaporated from and at 212° Fahr. per square foot of total heating surface was 9.90 lbs. per hour.

The average rate of transmission of heat through the material of the boiler was 9,560 thermal units per square foot of total heating surface per hour.

*Fuel Consumption.*—The total fuel burned was equivalent to 7,380 lbs. per hour. This would amount to a gross consumption of 2.48 lbs. of total fuel per I.H.P. of the main engines per hour; but assuming that 6.57 per cent. of the total amount was consumed in making steam for the three auxiliary engines, as already explained, this would reduce the net consumption of fuel on behalf of the main engines alone to 6,900 lbs. per hour, or 2.32 lbs. per I.H.P. per hour, which is equivalent to 2.30 lbs. of carbon value per I.H.P. per hour.

*Engine Efficiencies.*—The total I.H.P. of the main engines was 2,977; and the total gross feed water used per hour by the main engines and the three auxiliary engines which were at work throughout the trial was 66.180 lbs. This would amount to 22.23 lbs. of gross feed water per I.H.P. of the main engines per hour; but, as was shown in an earlier paragraph, 6.57 per cent. or 4,350 lbs. per hour of the total feed water was probably used by the three auxiliary engines; so that the net feed water used by the main engines alone would be 61,830 lbs. per hour, which is equivalent to 20.77 lbs. of net feed water per I.H.P. per hour. The total actual heat received by the gross feed water per minute was 1,169,000 thermal units, which is 66.1 per cent. of the whole heat of combustion. Similarly the actual heat received by the

COMPARATIVE RESULTS OF THE TRIALS OF FIVE SCREW-STEAMERS, S.S. *METEOR*, *FUSI YAMA*, *COLCHESTER*, *TARTAR*, *IONA*, AND ONE PADDLE-STEAMER, P.S. *VILLE DE DOUVRES*.

| | | *Meteor.* | *Fusi Yama.* | *Colchester.* | *Tartar.* | *Iona.* (Committee.) | *Iona.* (Chief Eng.) | *Ville de Douvres.* | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Name of vessel, | | | | | | | | 1 |
| 2 | Date of trial, | 1888 24 June | 1888 14, 15 Nov. | 1889 9 Nov. | 1889 27 Nov. | 1890 13 & 14 July | 1890 15 August | 1891 8 Sept. | 2 |
| 3 | Duration of trial, hours | 17.15 | 13.95 | 10.88 | 10.08 | 16 | 10.88 | 9 | 3 |
| 4 | Type of engines, | triple | compound | twin compd. | triple | triple | triple | Compd. Inclined. | 4 |
| 5 | Cylinder diameter, high pressure, ins. | J 29.37 | N 27.35 | (two) N 30 | N 26.03 | J 21.88 | J 21.88 | N 50 12 | 5 |
| 6 | " " intermediate, ins. | J 44.03 | ... | ... | J 42.03 | N 34.02 | N 34.02 | ... | 6 |
| 7 | " " low pressure, ins. | J 70.12 | N 50.3 | (two) N 57 | J 68.95 | N 56.95 | N 56 95 | N 97 12 | 7 |
| 8 | Stroke, length, ins. | 47.94 | 33 | 36 | 42 | 39 | 39 | 72 | 8 |
| 9 | Boilers, number of main boilers | 2 | 1 | 2 | 2 | 2 | 2 | 4 | 9 |
| 10 | " single-ended or double-ended, | double | single | double | double | single | single | single | 10 |
| 11 | Furnaces, total number, | 12 | 3 | 12 | 8 | 4 | 4 | 12 | 11 |
| 12 | Heating surface, total, square feet | 6,648 | 2,257 | 5,820 | 5,226 | 3,160 | 3.160 | 7,340 | 12 |
| 13 | " " tubes, square feet | 5,760 | 1,689 | 4,770 | 4,366 | 2,590 | 2 590 | 6,280 | 13 |
| 14 | Grate area, square feet | 208 | 52 | 220 | 161 | 42 | 42 | 236 | 14 |
| 15 | Total heating surface to grate area, ratio | 32 0 | 43.4 | 26.5 | 32 5 | 75.2 | 75 2 | 31.1 | 15 |
| 16 | Tube surface to grate area, ratio | 27.7 | 32.5 | 21.7 | 27.1 | 61.7 | 61.7 | 26 6 | 16 |
| 17 | Grate area to flue area through tubes, ratio | ... | 4.0 | 5.5 | 4.5 | 2.3 | 2.3 | 6.7 | 17 |
| 18 | " " area through funnel, ratio | 5.0 | 3.2 | 4.8 | 4.2 | 1.4 | 1.4 | 5 5 | 18 |

| | *Mean Pressures.* | Lbs. per sq. inch. | Lbs. per square inch. | |
|---|---|---|---|---|
| 19 | Boilers, working pressure, | 150 | 150 | 19 |
| 20 | Steam chests, | 150 | 150 | 20 |
| 21 | Initial, high pressure, | 144 | 144 | 21 |
| 22 | " intermediate, | 138 | 138 | 22 |
| 23 | " low pressure, | 132 | 132 | 23 |
| 24 | Mean, high pressure, | 72.5 | 72.5 | 24 |
| 25 | " intermediate, | 34.5 | 34.5 | 25 |
| 26 | " low pressure, | 15.5 | 15.5 | 26 |
| 27 | Vacuum, | 25 | 25 | 27 |
| 28 | Mean effective pressure, | 22.5 | 22.5 | 28 |
| 29 | Revolutions per minute, | 76.5 | 76.5 | 29 |
| 30 | Piston speed, feet per minute, | 1,050 | 1,050 | 30 |
| 31 | Indicated horse-power, | 1,000 | 1,000 | 31 |
| 32 | " " per square foot of grate, | 4.8 | 4.8 | 32 |
| 33 | " " per square foot of heating surface, | 0.15 | 0.15 | 33 |
| 34 | " " per ton displacement, | 0.5 | 0.5 | 34 |
| 35 | Displacement, tons, | 2,000 | 2,000 | 35 |
| 36 | Coal consumption per hour, lbs. | 2,000 | 2,000 | 36 |
| 37 | " " per indicated horse-power, lbs. | 2.0 | 2.0 | 37 |
| 38 | " " per square foot of grate, lbs. | 9.6 | 9.6 | 38 |
| 39 | Speed, knots, | 12.5 | 12.5 | 39 |
| 40 | Coal consumption per knot, lbs. | 160 | 160 | 40 |
| 41 | Displacement per indicated horse-power, tons | 2.0 | 2.0 | 41 |
| 42 | Coal consumption per ton displacement per knot, lbs. | 80 | 80 | 42 |

| | *Mean Pressures.* | Lbs. per sq. inch. | | Lbs. per square inch. | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 19 | Mean boiler pressure above atmosphere, | 145.2 | 56.84 | 80.5 | 143 6 | 165.0 | 162.0 | 105.8 | 19 |
| 20 | " admission " high pressure cylinder above atm., | 134.4 | 50.3 | 64.3 / 59.4 | 121.4 | 142.5 | 147.8 | 89.2 | 20 |
| 21 | " effective " high pressure cyl., | 58 46 | 30.74 | 45.65 / 42.07 | 36.89 | 46.65 | 47.33 | 55.49 | 21 |
| 22 | " " " intermediate " | 19.50 | ... | ... | 20.07 | 20 44 | 20.21 | ... | 22 |
| 23 | " " " low pressure " | 12.38 | 10.87 | 13.42 / 12.42 | 7.18 | 7.16 | 7.96 | 15.54 | 23 |
| 24 | " " " total reduced to low pressure cyl., | 29.9 | 19.9 | 24.8 | 19.8 | 21.13 | 21.95 | 30.17 | 24 |
| 25 | " exhaust " low pressure " below atm., | 11.6 | 10.9 | 10.6 / 10.5 | 10.5 | 12.74 | 12.8 | 8.78 | 25 |
| 26 | " vacuum in condenser below atm., | 12.17 | 12.48 | 12.49 | 12.9 | 13.88 | 13.76 | 10.12 | 26 |
| 27 | Revolutions per minute, mean, . revs. | 71.78 | 55.59 | 86.0 / 87.1 | 70.0 | 61.1 | 63.9 | 36.82 | 27 |
| 28 | Piston constant, high pressure cyl., H.P. | 11.31 | 5.36 | 10.71 / 10.84 | 7.73 | 4.41 | 4.61 | 25.99 | 28 |
| 29 | " " intermediate " H.P. | 26 00 | ... | ... | 20.42 | 10.82 | 11.32 | ... | 29 |
| 30 | " " low pressure " H.P. | 66 65 | 18.32 | 39.55 / 40.06 | 55.27 | 30.54 | 31 93 | 98.56 | 30 |
| 31 | Indicated horse power, high p. " I.H.P. | 662 | 168.2 | 490.3 / 457.9 | 283.7 | 205 6 | 221.0 | 1,444 | 31 |
| 32 | " " inter. " I.H.P. | 507 | ... | ... | 408.5 | 221.2 | 231.7 | ... | 32 |
| 33 | " " low p. " I.H.P. | 825 | 203.1 | 532.2 / 499.3 | 395.2 | 218.6 | 255.0 | 1,533 | 33 |
| 34 | " " mean total I.H.P. | 1,994 | 371.3 | 1,022 5 / 957.2 | 1,087.4 | 645.4 | 707.7 | 2,977 | 34 |
| 35 | Fuel burnt per minute, . . lbs. | 66.75 | 16.45 | 95.7 | 32.0 | 15.7 | 16.3 | 123 | 35 |
| 36 | " " per hour, . . lbs. | 4,005 | 987 | 5,742 | 1,920 | 942 | 978 | 7,380 | 36 |
| 37 | " " per square foot of grate area per hour, lbs. | 19.25 | 18.98 | 26.1 | 11.93 | 22.4 | 23.3 | 31.3 | 37 |
| 38 | " " per square foot of total heating surface per hour, lbs. | 0.602 | 0.437 | 0.987 | 0.367 | 0.298 | 0.310 | 1.01 | 38 |
| 39 | " " per indicated horse power per hour, . lbs. | 2.01 | 2.66 | 2.90 | 1.77 | 1.46 | 1.38 | 2.48 / 2 32* | 39 |
| 40 | Carbon-value of 1 lb. of fuel as used, lbs. | 0.878 | 0.878 | 0.913 | 1.031 | 1 02 | ... | 0.99 | 40 |
| 41 | " " equivalent per indicated horse power per hour, lbs. | 1.76 | 2.33 | 2.65 | 1 82 | 1.49 | ... | 2.46 / 2.30* | 41 |

| | Name of vessel, . . . . . | *Meteor.* | *Fusi Yama.* | *Colchester.* | *Tartar.* | *Iona.* (Committee.) | *Iona.* (Chief Eng.) | *Ville de Douvres.* | |
|---|---|---|---|---|---|---|---|---|---|
| 42 | Feed-water per minute, . . lbs. | 497.7 | 131 | 717 | 359.4 | 143.6 | ... | 1,103 | 42 |
| 43 | " " per hour, . . lbs. | 29,860 | 7,860 | 43,020 | 21,564 | 8,616 | ... | 66,180 | 43 |
| 44 | " " per square foot of total heating surface per hour, lbs. | 4.49 | 3.48 | 7.39 | 4.13 | 2.73 | ... | 9.02 | 44 |
| 45 | " " per lb. of fuel, . lbs. | 7.46 | 7.96 | 7.49 | [11.23]† | 9.15 | ... | 8.97 | 45 |
| 46 | " " per lb. of fuel from and at 212° F., lbs. | 8.21 | 8.87 | 8.53 | [13.06]† | 10.63 | ... | 9.84 | 46 |
| 47 | " " per lb. of carbon-value from and at 212° F., lbs. | 9.62 | 10.10 | 9.34 | [12.67]† | 10.42 | ... | 9 94 | 47 |
| 48 | " " per indicated horse power per hour, lbs. | 14.98 | 21.17 | 21.73 | [19.83]† | 13.35 | ... | { 22.23 / 20 77* } | 48 |
| 49 | Calorific value of 1 lb. of fuel as used, Th. U. | 12,770 | 12,760 | 13,280 | 14,995 | 14,830 | ... | 14,390 | 49 |
| 50 | Percentage of line 49 taken up by feed water, p. cent. | 62.0 | 67.2 | 62.0 | ... | 69.2 | ... | 66.1 | 50 |
| 51 | " " " " carried away by furnace gases, p c. | 21 9 | 23.5 | 28.0 | 22.1 | 16.2 | ... | 26.8 | 51 |
| 52 | " " " " lost by imperfect combustion, p. c. | 3.6 | 0.0 | 1.3 | 0.0 | 0.0 | ... | 0.0 | 52 |
| 53 | " " " " used in evaporating moisture in coal, p.c. | 1.2 | 0 9 | 0.4 | 0 0 | 0.0 | ... | 0 0 | 53 |
| 54 | " " " " unaccounted for, p.c. | 11.3 | 8.4 | 8.3 | ... | 14.6 | ... | 7.1 | 54 |
| 55 | Heat taken up by feed-water per min., Th. U. | 528,600 | 141,100 | 788,700 | [403,600]† | 161,100 | ... | { 1.169,000 / 1,092,000* } | 55 |
| 56 | " turned into work per min., Th. U. | 85,240 | 15,870 | 84,630 | 46,490 | 27,590 | 30,250 | 127.300 | 56 |
| 57 | " taken up by feed-water per indicated H. P. per min., Th. U. | 265.6 | 380.0 | 398.4 | [371.2]† | 249 6 | ... | { 392.7 / 366.8* } | 57 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 58 | Efficiency of boiler (line 50), per cent. | 62.0 | 67.2 | 62.0 | ... | 69.2 | ... | 66.1 | 58 |
| 59 | " of engine (line 56÷line 55), p.c | 16.1 | 11.2 | 10.7 | [11.5]† | 17.1 | ... | 11.7* | 59 |
| 60 | " of engine and boiler combined (line 58 × line 59), per cent. | 10.0 | 7.6 | 6.6 | 9.7 | 11.8 | ... | 7.7* | 60 |
| 61 | Mean velocity of steam through water surface in boilers per min., ft. | ... | 6.28 | 8.60 | 3.43 | 1 61 | ... | 8.61 | 61 |
| 62 | Space occupied by boilers per I.H.P., c. ft. | 2.72 | 4.53 | 2.52 | 4.33 | 4.15 | 4.15 | 2 09 | 62 |
| 63 | Weight of engines, boilers, &c., with water, per I.H.P., ton | 0.20 | 0 27 | 0.20 | 0 27 | 0.31 | 0.31 | 0.12 | 63 |
| 64 | Clearance volume, high p. cyl., per cent. | 12.4 | 8 5 | (two) 9.39 | 14.51 | 12.41 | 12.41 | 15.0 | 64 |
| 65 | " " inter. " per cent. | 9.3 | ... | ... | 9.25 | 10.11 | 10.11 | ... | 65 |
| 66 | " " low p. " per cent. | 8.02 | 5.0 | (two) 6.23 | 5.10 | 7 64 | 7.64 | 12.0 | 66 |
| 67 | Clearance surface high p. " square feet | ... | 17.3 | (two) 22.6 | 25.4 | 12.75 | 12.75 | 84.73 | 67 |
| 68 | " " inter. " square feet | ... | ... | ... | 40.1 | 29.14 | 29.14 | ... | 68 |
| 69 | " " low p. " square feet | ... | 42.5 | (two) 56.9 | 79 6 | 49.5 | 49.5 | 211.46 | 69 |
| 70 | Speed of vessel, mean, during trial, knots | 14.6 | ... | 14.4 | ... | 8.6 | 9.0 | 17.1 | 70 |
| 71 | Mean temperature of outer air, Fahr. | ... | 55° | 55° | 55° | 62° | 91° | 64° | 71 |
| 72 | " " " chimney gases, Fahr | 791° | 578° | 835° | 477° | 452° | ... | 910° | 72 |
| 73 | " " " feed water, Fahr. | 163° | 129.5° | 113° | 101° | 106° | 157° | 158° | 73 |
| 74 | " " " boiler steam, Fahr. | 363° | 304° | 324° | 362° | 373° | 371° | 342° | 74 |
| 75 | " " " circulating water, Fahr. | ... | ... | ... | ... | 55.8° | 78.6° | 61.7° | 75 |
| 76 | " " " discharge water, Fahr. | ... | ... | ... | ... | 75.5° | 94.4° | 85.0° | 76 |

J, Jacketed. N, Not Jacketed. *Allowing for the three auxiliary engines. †See pp. 363, 366, 367, Vol. II.

net feed water used by the main engines would be 93.43 per cent. of this amount, or 1,092,000 thermal units per minute. The absolute engine efficiency of the main engines alone, or ratio of the heat turned into work by them to the heat given to the net feed water, was 11.7 per cent.

*Total Efficiency.*—The combined efficiency of the boilers and engines, or ratio of the heat turned into work to the total heat of combustion of the fuel, allowing for the 6.57 per cent. of the feed water which was consumed by the three auxiliary engines, was $0.661 \times 0.117$, which is equivalent to 7.7 per cent.

*Steam from Indicator Diagrams.*—The following are the results of measurements made upon the indicator diagrams, taken to ascertain the proportion of steam accounted for by them. The actual weight of net feed water used by the main engines per revolution was 27.99 lbs.:

| Proportion of Steam Accounted For by Indicator Diagrams. | Lbs. per Revolution. | Percentage of Total Feed. | Percentage Present in Cylinder as Water. |
|---|---|---|---|
| Steam present in high-pressure cylinder after cut-off, when the pressure was 81.2 lbs. per square inch above the atmosphere, | Lbs. 22.57 | Per cent. 80.6 | Per cent. 19.4 |
| Steam present in low-pressure cylinder near end of expansion, when the pressure was 0.8 lb. per square inch below the atmosphere, | 20.29 | 72.5 | 27.5 |

*Speed of Vessel.*—The following extract from the ship's log has been kindly furnished by M. Lecointe:

| Time. | Observations. | Distance Measured from Chart. |
|---|---|---|
| 8 September, 1891. | | Nautical Miles. |
| 7.30 a.m. | Left Ostend harbor, | 0 |
| 10.30 " | Passed Nord-Hinder light vessel, | 26 |
| 12.14 p.m. | Passed Outer-Gabbard light vessel, (Speed reduced for fourteen minutes.) | 57 |
| 2.20 " | Passed Corton light vessel, | 90 |
| 4.18 " | Repassed Outer-Gabbard light vessel, | 125 |
| 6.04 " | Repassed Nord-Hinder light vessel, | 156 |
| 7.27 " | Returned to Ostend harbor, | 182 |

The mean speed between the times of passing Nord-Hinder light vessel on the outward journey and arriving in Ostend harbor, which includes nearly the whole of the trial, was therefore 17.1 knots. The mean speed over the trial, excluding the passage from Outer-Gabbard light vessel to Corton light vessel, during which the fourteen minutes of slowing down occurred, was 17.5 knots.

Accompanying this report is a table, showing the leading results of the trial of the *Ville de Douvres*, and beside these are placed the corresponding figures for the six trials which have been reported on previously, namely, those of the *Meteor*, *Fusi Yama*, *Colchester*, *Tartar*, *Iona* and the subsequent trial of the *Iona*, carried out by the chief engineer of the vessel.

## XIX.

# EXPERIMENTS WITH BASIC STEEL.

By W. H. White, C. B., F. R. S., Director of Naval Construction and Assistant Controller, Royal Navy.

[Paper read before the Iron and Steel Institute of Great Britain, May 26, 1892.]

In this paper it is proposed to summarize the results of an experimental inquiry into the qualities of steel, of shipbuilding quality, made by the basic process, which inquiry has been conducted by officers of the Admiralty during the last six years.

The subject is one of considerable interest and importance to both the makers and users of mild steel, and it seemed desirable that the statement I have to make should be submitted to the Iron and Steel Institute, rather than to any other technical association.

It is well known that, about seven years ago, steel made by the basic process was used to a certain extent in mercantile shipbuilding, and subsequently ceased to be employed. At that time I was not in the public service, being engaged in the conduct of a large private shipbuilding establishment on the Tyne. Consequently I was personally familiar with this first chapter in the history of basic steel as applied to ship construction. It would be out of place to enter into any details here, nor is it necessary to do so. At the same time it has an important bearing on action subsequently taken by the Admiralty, and is therefore mentioned.

In March, 1886, Mr. Percy Gilchrist made an official application to the Admiralty, on behalf of makers of steel using the basic process, for a searching investigation into the qualities of that material. It was my duty, as director of naval construction, to advise their lordships on this matter. With a full knowledge of what had happened in mercantile practice, I recom-

mended compliance with the request, and no time was lost in prosecuting the inquiry.

This decision of the Admiralty was in complete accordance with its recognized policy of enlarging, as much as possible, the sources of supply for shipbuilding materials. Further, it was recognized that the encouragement of the basic process was a matter of national importance, since that process, if successful, made British steelmakers much less dependent on supplies of foreign non-phosphoric ores, and enabled native phosphoric ores to be utilized.

Six firms granted facilities to Admiralty officers to visit their works, and to select freely samples of basic steel for purposes of testing. These samples, for the most part, were taken from plates which were being rolled in execution of current orders; they were not specially manufactured to comply with the Admiralty specification for steel of shipbuilding quality, except in a few instances. Consequently there were considerable differences in the strength and ductility of various samples, and the range of the experiments was very great. The materials tested included specimens of both open-hearth and Bessemer manufacture.

In July, 1887, I read before the Institution of Naval Architects a paper, "On Some Recent Experiments with Basic Steel," in which the details of the experiments are given. To the Transactions of that Institution I must refer those who desire to obtain complete information; and in the same volume they will find a valuable paper by Mr. Martell, the chief surveyor of Lloyd's Register, giving the results of an extensive series of tests which he had conducted on basic steel, with special reference to mercantile shipbuilding.

The experiments of 1886–7 constituted a most searching preliminary investigation into the qualities of basic steel, when subjected to tensile, bending and percussive strains; when welded, punched, sheared, annealed, heated and reheated; and when subjected to rough usage and hard work, inevitable to the processes of shipbuilding. Writing in 1887, I said: "The experimental inquiry has been as thorough as, if not more thorough than, that which preceded the adoption of mild (acid) steel

by the Admiralty in 1875. As a whole the results of the investigation have been very satisfactory, affording good evidence of the trustworthiness of basic steel. The only extension which suggests itself as desirable in this series of experiments, is in the direction of tests of riveted work."

One other statement should be made. At the outset basic steelmakers endeavored to induce us to lower the Admiralty standard of minimum tensile strength from 26 tons per square inch to 23 or 24 tons. This concession could not be made. No doubt it would have simplified the problem to be dealt with by the steelmakers. On the other hand, it is a necessity for war ships, built on comparatively light scantlings, that, for the maintenance of both strength and stiffness, the minimum tensile strength above mentioned shall be maintained.

Moreover, it speedily appeared that basic steelmakers were underestimating what their process could accomplish ; and that not merely could Admiralty conditions for shipbuilding steel be met, but that satisfactory basic steel could be produced in which ultimate tensile strengths of 32 to 36 tons per square inch could be associated with good ductility and working qualities.

Having obtained these satisfactory experimental results, the Admiralty placed, in 1887, a small trial order for basic steel plates and bars, which were used in some of the less important portions of ships building at Chatham, and were favorably reported on. It was then decided provisionally to place basic steel on the same footing as Bessemer acid steel, the use of the latter material in Admiralty practice being limited to the less important portions of ships' structures. Further, it was arranged to proceed with tests of basic steel in the form of riveted samples, as soon as might be convenient.

In conversation with steelmakers I have often been asked why we attach so much importance to tests of riveted samples, and why we are not content with the tensile, bending and quenching tests which are made at the works. It may be convenient, therefore, to explain briefly.

Fifteen or sixteen years ago, when I was conducting at Pembroke a series of experiments on acid steel made by the Bessemer

and open-hearth processes—I being at the time an assistant to my friend Sir N. Barnaby (late Director of Naval Construction)—it was discovered that the preparation for, and performance of, the process of riveting constituted a crucial test. Specimens of Bessemer steel proved equal to specimens of open-hearth steel in tensile, percussive and forge tests, in capacity for welding, and in the loss of strength consequent on punching. But, when riveted samples were tested—the plates from which those samples were cut being the same that had been used in the previous series of experiments—the Bessemer acid steel proved inferior to, and much less trustworthy than, the open-hearth steel. Repeated experiments only confirmed this conclusion, and consequently it was decided in future Admiralty practice not to employ Bessemer acid steel in the more important part of ships' structures, where severe tensile stresses have to be borne. This decision was not then announced in set terms. The Admiralty desired not to prejudice any mode of manufacture. In our specifications, however, power was always taken to order any portion of the material that might be selected of open-hearth manufacture.

Steelmakers appear to have overlooked the fact that the crucial character of riveted tests was fully explained in a paper on "The Use of Steel in Naval Construction," read by Sir Nathaniel Barnaby before this Institute in 1879. Again and again representations have been made to us that our insistence on the specification of open-hearth steel for certain classes of work was unreasonable, and triumphant reference had been made to comparative tests of sample strips—non-riveted—where converter steel has compared favorably with open-hearth. To all such persons I commend the reading of Sir N. Barnaby's paper, and can add that our later experience only confirms the conclusions therein recorded. With converter steel riveted samples have given less average strength, greater variations in strength, and much more irregularity in modes of fracture than similar samples of open-hearth steel.

Resuming my narrative of Admiralty experiments, it must be stated that the first tests with riveted samples of Bessemer basic

steel were made by our officers at the works of a private firm. The results are tabulated in Tables I and II. In the former are the ordinary tensile tests of six unannealed samples cut from one "blow." The average ultimate tensile strength was 29.9 tons per square inch, and the elongation in 8 inches, 21.7 per cent. The tests of four annealed samples are also given. Table II contains the results of tests on riveted samples, made from the same "blow." The majority of the experimental joints were made to represent fairly portions of the laps and butts of the bottom plating of a ship. In a few cases, the rivets were either closely pitched or otherwise disposed, so that the plate should fracture before the rivets sheared. The rivets were of basic steel, and proved to have excellent working qualities, while their shearing strength was practically identical with that of rivets of equal size made of open-hearth acid steel. In the cases where the plate fractured, the mean breaking stresses were respectively 23.6 tons per square inch for the close-pitched rivets and 26.7 tons per square inch for the larger pitch. These figures have to be compared with 29.9 tons per square inch for the unpierced plate.

It is unnecessary to analyze the figures further, as they are given chiefly because they represent the first tests made on basic riveted samples by Admiralty officers.

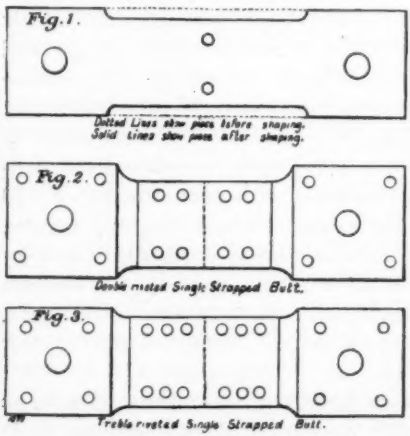
Fig. 1.
Dotted Lines show plate before shaping.
Solid lines show plate after shaping.
Fig. 2.
Double riveted Single Strapped Butt.
Fig. 3.
Treble riveted Single Strapped Butt.

Tables III and IV contain the results of the earliest series of experiments on riveted samples of basic Bessemer steel, made at Pembroke in 1888. These experiments were conducted on exactly the same lines as those made in 1875–'83 on acid steel, so that the results might be compared. Figs. 1, 2 and 3 show the details of the samples used in test-

ing the effects of punching and riveting. Notes on the tables contain nearly all necessary explanations. Up to the stage of riveting, the basic Bessemer samples compared well with open-hearth acid samples previously tested. Turning to Table IV, however, much less satisfactory results are reached. Fracture occurred in a most irregular fashion, and at very low breaking stresses in many instances. No method of averages fairly represents such conditions, and the figures given speak for themselves. It may be added that, with open-hearth acid samples of $\frac{1}{2}$-in. steel plates with $\frac{3}{4}$-in. rivets and countersunk points, the breaking stress on the sectional area of the plate across a line of rivet holes was found to be as great as that of an unperforated plate. It will be seen that, in the basic Bessemer samples of similar character, the breaking stress varied from equality to that of the unperforated plate down to about 63 per cent. of the full strength.

These results were admittedly unsatisfactory, but practically no worse than had been obtained with acid Bessemer samples in some previous trials.

The representatives of the Bessemer basic manufacture considered that these limited trials were not conclusive, and their view was doubtless a reasonable one. At the same time it was thought preferable to give precedence to trials of open-hearth basic steel, before repeating trials on the Bessemer make. Owing to various causes, for which the Admiralty are not responsible, these trials of open-hearth basic steel have been long deferred—from the end of 1888 to the end of 1891. The further trials of basic Bessemer steel are now in progress, but the results cannot be given.

Tables V and VI contain the particulars of the first series of tests on riveted samples of open-hearth basic steel made at Pembroke in 1889. This was supplied by the same firm which had furnished the basic Bessemer steel of which tests appear on Tables III and IV.

The experiments were made on the same lines as in previous cases.

It will be seen from Table V that the material supplied in its un-

perforated condition was below the minimum of tensile strength, viz., 26 tons per square inch, fixed by the Admiralty for ship-work.

It stood punching and working well, and in most of the riveting tests it also gave better results than the basic samples which preceded.

On the other hand, there were cases in which the fracture of riveted samples was irregular, particularly with pan heads and snap-pointed rivets, which is a mode of fastening used only in the internal work of ships. For the bottom plating and all important portions of the structure, rivets with countersunk points are invariably used.

The results indicated a want of uniformity in the material, and led to a close investigation of the plates by representatives of the firm. Their opinion was that some of the plates had been injured in the process of annealing, and that consequently the tests were not a trustworthy guide to the quality of the material.

It has been preferred, however, to give the actual results of tests with this explanation, rather than to make a selection from the series of experiments. Such a selection might, of course, be unduly favorable to the process of manufacture.

Up to this point the Admiralty had purchased the material used in the Pembroke experiments, and on the basis of the quotations sent in all the material had been ordered from one firm.

Mr. Gilchrist now offered to supply, without charge to the Admiralty, materials made by several representative firms, so that the series of experiments might be continued on a larger scale. This offer was accepted in November, 1889.

Much time was occupied in waiting for the material, and no unavoidable loss of time occurred on the part of the Admiralty in carrying out the further tests.

The results are given in Tables VII to XIV, and represent tests on open-hearth basic steel made by four different firms.

In the case of each firm the series of tests was identical with that above described.

Tables VII and VIII give the particulars of the behavior of

samples made from material supplied by the same firm as had previously furnished open-hearth and Bessemer basic steel for the Pembroke experiments.

It will be seen from Table VII that the tensile strength of this material was about the minimum admitted by the Admiralty for shipbuilding quality; that it stood the punching, &c., well; and, what is more important, in the riveting tests the results were uniform and excellent.

These results appear to justify the opinion which had been given by the representatives of the firm as to the material tested in Tables V and VI, having been accidentally damaged during manufacture.

The corresponding tests for samples of material supplied by another firm are given in Tables IX and X. Here, also, the tensile strength of the unperforated plates is about at the lower limit admitted by the Admiralty, and the results of the riveting tests are excellent.

Tables XI and XII contain a still more interesting series of tests, seeing that they deal with material where the strength of the unperforated plates is actually above the 30 tons named as the upper limit in Admiralty specifications for ship quality. The ductility is good, the material stands punching, and the riveting tests are remarkably good.

Still another series of tests, representing results obtained by a fourth firm, are given in Tables XIII and XIV. Here the ultimate tensile strength is, as nearly as possible, the mean fixed by the Admiralty conditions for plates for shipwork. The mean extension in 8 inches is 25.8 per cent. as against the 20 per cent. fixed in the Admiralty conditions. The material stands punching and working well, and the tests of riveted samples are entirely successful.

These later tests of material, supplied from different parts of the country, and by different makers, afford conclusive evidence that the basic process, applied by competent makers to the production of open-hearth steel, may be trusted to give us results no less satisfactory than those obtained with acid open-hearth steel.

The method of averages is, of course, open to question, as has been remarked above, but the following short summary is interesting:

With open-hearth acid steel of standard quality, a large series of experiments has given the following results:

| | Tons per square inch. |
|---|---|
| Tensile strength of plain strips, . . . . . | 28.2 |
| Tensile strength of strips ½ in. in thickness with ⅞-in. holes punched before shaping, . . . . . | 22.1 |

Or a loss through punching of nearly 22 per cent.

Taking that make of basic steel shown in Tables XIII and XIV—

| | Tons per square inch. |
|---|---|
| Tensile strength of plain strips is . . . . | 27.6 |
| And that of strips of the dimensions and character named above, . . . . . | 24.6 |

Showing a loss due to punching of about 11 per cent.

The material of higher tensile strength, shown in Tables XI and XII—

| | Tons per square inch. |
|---|---|
| Has a normal strength of, . . . . . | 31.3 |

The loss due to punching is only about 2 tons per square inch, or less than 7 per cent.

With the milder qualities of basic steel there is practically no loss in punching, but these qualities are not so suitable for our requirements as the other two.

Turning to riveting, and without going into details, it may be said that, with the standard open-hearth acid plates, there is no loss in ultimate tensile strength per square inch of sectional area when rivets and countersunk points are used; and for practical purposes the same thing is true with basic open-hearth steel. In fact, some of the tables show a gain in the riveted samples as compared with the unperforated strips.

With snap-pointed rivets, acid open-hearth steel loses about 12 to 13 per cent. as compared with unperforated samples. For similar tests of open-hearth basic steel there are in many in-

stances no losses whatever. On the whole, the basic specimens compared exceedingly well in all respects with those made by the acid process.

The shearing tests of the rivets made by the basic process are practically identical with those of rivets made by the acid process.

| | Tons. |
|---|---|
| The single shear of a $\frac{3}{4}$-in. rivet with countersunk point is, for the acid steel, . . . . . | 11.6 |
| And for the average of the basic steel, . . . | 11.5 |
| The double shear of a $\frac{3}{4}$-in. rivet is, with acid steel, about . . . . . | 21.2 |
| And with basic steel about . . . . . | 21.3 |

With these results before them, the Admiralty decided to admit basic steel made in the open hearth, on practically the same terms, as regards shipwork, as those on which acid open-hearth steel has been admitted. The step has not been taken without the fullest investigation. In fact much more has been done in the way of preliminary testing of basic steel than was done with acid steel. The new process will, no doubt, have to be carefully watched, in order that uniformly good results may be obtained.

It may be said that the tests, of which an account has been given in this paper, while satisfactory, were made on material much of which was specially manufactured for the purpose.

This is perfectly true; but, on the other hand, if such satisfactory results can be obtained in sample orders, it is clearly only a question of management and precaution if similar results are to be obtained on a large scale.

Should the manufacturers of basic steel in the open hearth succeed in obtaining a share of the Admiralty orders for shipbuilding purposes, it will be necessary for them to use every effort to secure, in the material supplied, qualities equal to those which have been proved to exist in the experimental samples.

Close watch will be kept upon the working of the material in the shipyards, and the Admiralty system provides for frequently making what are termed "casual tests" of the material in the

dockyards, supplementing those made at the works of the manufacturers by the resident overseers.

In short, as users as well as buyers, the Admiralty can with safety enter upon the use of a material which has satisfactorily passed all preliminary tests, being assured that, should any deterioration in quality occur in the supplies as compared with the samples, the facts will be immediately ascertainable.

It will be noted that this paper has dealt exclusively with basic steel for shipbuilding purposes. It is our practice to gain experience of a new material for shipwork before considering its adoption for boiler making. This was done when acid mild steel was introduced, and the same course is still being followed. For boiler tubes, however, basic open-hearth steel is already admitted by the Admiralty.

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## Discussion.

Mr. Gilchrist was the first speaker on Mr. White's paper. Referring to the tables which had been quoted by the author, in which the details were given of the Admiralty tests with basic steel, he pointed out that three out of the four makers whose productions had been subject to trial, had used ordinary pig containing 2.6 to 2.7 per cent. of phosphorus.

Mr. Arthur Cooper thought Mr. White must be congratulated upon the very efficient and thorough manner in which he had carried out his experiments. The results given in Tables I and II of Mr. White's paper confirmed the results of Mr. Cooper's tests made in Middlesbrough at the North-Eastern Steel Works on planed unperforated strips of basic Bessemer steel, at the time the firm were supplying material for shipbuilding under Lloyd's survey. The speaker had had no experience with basic open-hearth steel, but he was not at all surprised that Mr. White had arrived at the conclusion he had, viz., to admit basic open-hearth on the same terms as acid open-hearth, and he saw no reason to doubt that, after he had completed his further trials of basic Bessemer, his results would be equally

satisfactory. As regards the experiences of his firm they supplied something like 1,000 tons of basic Bessemer in the early days under the very stringent inspection of Lloyd's surveyors with satisfactory results so far as quality of the steel was concerned, but as a very large demand came upon them about that time for a much softer quality of steel, viz., for billets for wire, and for slabs and bars for tin plates, it suited them much better for commercial reasons to take up the softer trade for which the plant and arrangements were made, rather than to follow up the manufacture of steel for shipbuilding, for which they were not so well laid out, inasmuch as having no angle or plate mills they had to supply the shipbuilding material in the form of blooms and slabs to neighboring works to be rolled down into the finished product. Altogether they found the business a very inconvenient one.

With respect to what Mr. White said as to reducing the tensile strength, Mr. Cooper thought he had something to do with the suggestion to which the author referred, but the idea was not to get the minimum standard reduced from 26 tons to 23 tons, but to get a lower additional class fixed for soft basic steel or ingot iron, so as to enable this softer steel to compete with wrought iron. It was not expected to get for this material much reduction from that of the iron scantlings, but it was thought that this would form a sort of middle class, and that of this material a ship could be produced superior to iron in point of quality and at about the same cost. He quite agreed with Mr. White that owing to recent developments there did not now appear to be the same necessity for the lower limit as in the earlier days, because it was now quite as easy to make steel of the higher tensile strain as of the lower strength.

Mr. Snelus wished to call attention to the list of riveted samples. The author had said that up to the stage of riveting the basic Bessemer samples compared well with open-hearth acid samples previously tested. Turning, however, to the table which contained the results of experiments made at Pembroke Dockyard in 1888, to ascertain the effect of riveting on basic Bessemer steel, much less satisfactory results were reached. Fracture

had occurred in a most irregular fashion, and at very low breaking stresses in many instances. No method of averages fairly represented such conditions. With open-hearth acid samples of ½-in. plates with ¾-in. rivets and countersunk points, the breaking stress on the sectional area of the plate across the line of rivet holes was found to be as great as that of the unperforated plate. It was seen by reference to the table that in the basic Bessemer samples of similar character the breaking stress varied from equality to that of the unperforated plate, down to about 63 per cent. of the full strength. Commenting on these points, the fact that there was no reduction from perforation Mr. Snelus looked upon as unique, and he would like to ask the reason for so remarkable a result. He considered the basic steel a pure metal, and this was important, and only further experience was wanted to get uniformity with the product of the converter, as well as that of the open-hearth furnace. Mr. Snelus was sure that steel could be produced as cheaply in England as anywhere, but what was wanted was employment for the steel. He had lately been at Seraing, and there he had found that the contract for the iron work for a large Chinese iron works had been taken out of the hands of the English firms by a Belgian works. The design was from English hands, and Englishmen would be employed on the works, but English material would not be used, in spite of the welcome that any such order would receive at the present time. Mr. Snelus attributed this to the want of energy on the part of those who have the commercial control of English iron and steel works in this country.

In this respect we think Mr. Snelus was right. Our Continental competitors—not only in the iron and steel trade, by the way—show more enterprise in seeking and securing outlets for their produce; in fact they are better salesmen. The British manufacturer is rather given to despising those arts by which customers are obtained. "Those beggarly foreigners are so hungry for orders that they never let a thing pass," recently said the agent of a big north country firm; and, barring the epithet, the expression about describes the situation. Perhaps we have been spoiled by the period during which we had a practical

monopoly of many kinds of manufactured goods. We hardly yet realize that we must strive at every point—both in making and selling—if we do not wish to be passed by the "hungry foreigner," who, now he has forced admission to the feast, brings the keen appetite due to long abstinence. We perhaps are a little sluggish from repletion.

Mr. James Riley, in speaking of basic steel, said he would first like to express his appreciation, as a steel manufacturer, of the sympathetic attitude assumed by Mr. White and Mr. Martell in their dealings with the introduction of basic steel for shipbuilding purposes; and he also thought it was a fitting opportunity to refer to the indebtedness of the Institute to Mr. White for contributing the paper. Steelmakers perhaps did not always remember what they owed to gentlemen in official positions, but it would be well to think what would have been the position of the steel industry now, if Sir Nathaniel Barnaby, Mr. White and Mr. Martell had assumed only a passive attitude during that time. Mr. Riley wished to indorse all that the paper said as to the value of basic open-hearth steel, in the manufacture of which he had had experience. He would, however, say nothing about basic Bessemer, and this because he had had no experience as a manufacturer of that metal. He would remind his audience, however, that at the Glasgow meeting of the Institute in 1885 he had expressed a strong opinion that the proper way of utilizing the basic process was by the open hearth and not by the converter. Doubtless since that day he had seen reason to modify his views. Mr. Cooper had made good basic Bessemer steel, but Mr. Riley still held that the basic process was more fitted for the open hearth, which would produce the best basic as it did the best acid steel.

Reference had been made to the tests for basic steel made at the works over which Mr. Riley presides, and in this matter Mr. Martell had not shown himself so sympathetic as in others. Mr. Martell said he wanted to be informed upon what went into the furnace before he would pass the steel, but in that Mr. Riley considered he was going beyond his proper sphere of inquiry. Mr. Riley was quite willing to submit to any tests asked, but

so long as he complied with these, and produced a metal of the kind required, he thought that was all that should be asked, leaving him to get his results as best he might. It was what came out of, and not what went into the furnace, with which surveyors or overseers should have to deal. On this point the speaker and Lloyd's chief surveyor were at issue, and as neither would give way, the company with which Mr. Riley was connected had not for a time received orders for material which was under Mr. Martell's control. That, of course, has been to the loss of Mr. Martell's clients.

Sir Alfred Hickman said that the time was past when we should consider whether basic steel should be employed or not, for it was now an established fact that it should. The foreign makers had settled this, for if they produced it we must. He considered that basic steel must ultimately be the best, but up to the present the process was not complete, although it was progressing towards perfection. Mr. Riley preferred the open-hearth steel, but he very fairly stated that that was because he had had no experience with Bessemer. One of the improvements the speaker would mention was the method of introducing the ferro-manganese; it being now first put in a wooden box, which was then placed in the converter. In his works they had more certain and regular results when this plan was followed, although they were unable to give any reason for it. As a comment on what had been advanced as to the superiority of the open hearth over the converter, he would say if anything special and out of the way were required, do not use the open hearth but the converter.

Colonel Dyer, of Elswick, referred to the variation in results quoted by Mr. White for which no reason could be assigned. He thought that this might be explained by the fact that in solidification the impurities in the metal were driven to the middle of the ingot, and tests cut from parts made from the central part were therefore likely to prove less satisfactory than others. He had found, however, that when there was not so large a percentage of oxide present that the effect was less, and anyone who could devise a test for the purpose of determining

the presence of oxide would do a great deal to help the steel-maker.

DR. E. RILEY thought there was no question as to the importance of oxygen. He had some time ago been consulted about the manufacture of horseshoe nails, in the production of which there had been some trouble. Although they were all made from the same metal, it was found that a certain number of the nails, about one in every thirty or forty, were quite brittle. The phenomenon caused some little difficulty, but Dr. Riley was of opinion that it was due to oxygen. On inquiry he found that the pan in which the nails were annealed was not well luted at the cover, so that a certain small quantity of air leaked through, and this was enough to effect the nails near the joint.

MR. B. MARTELL said that he could hardly find words adequate to express his thanks to Mr. Riley for the manner in which he had alluded to the slight services which the speaker had been able to render to the steel manufacturers. It was so generally the other way, and he was quite accustomed to being classed with the fossils and obstructives of the shipbuilding world, especially, we might add, by inventors and exploiters whose schemes and devices he does not at once accept without preliminary test or inquiry. It was formerly truly said, Mr. Martell continued, that little enough was got out of the Admiralty in the way of information, although so much valuable material was obtained at public expense. Formerly it was advanced that the reason for secrecy was that the consent of the Board of Admiralty could not be obtained; but it was very evident that Mr. White could get this consent when he had a mind to do so.

All who knew the recent history of steel knew how unsatisfactory was the early production of basic steel. There was no need for Lloyd's then to condemn it, especially on the northeast coast, as no shipbuilder would look at it. For some time after it was not heard of, but after a time they were informed that Mr. Gilchrist was going to build a large ship entirely of basic steel. Lloyd's were invited to send a surveyor. They stipulated that the steel should be tested in the usual way, and this was agreed to. The angles were rolled by one firm and the plates by another,

so they sent representatives to the former in accordance with the usual custom, and it was gratifying to him to state that the results were such that he could quite confirm all Mr. White had said in his paper. That referred to angles, and he realized that the time would come when basic steel should be accepted with the same confidence as acid steel. Unfortunately he could not say anything about the plates on this particular job, as Mr. Gilchrist did not go on with the building of the ship, and therefore he would have to wait to know more. Mr. White's tables did not deal with plates above $\frac{1}{2}$ in. thick, but tests had been made with basic steel $\frac{7}{8}$ in. thick, and they were reported to be favorable to this extent, that the bend and temper tests were satisfactory, and here they had not gone to the lowest limits of softness as the tensile strength went up to 31.5 tons. The metal had not altered in character more than acid steel on being punched. With regard to Mr. Riley's remarks about what went into the furnace and what came out, the speaker had previously said that they had known no steel up to the time which was made with Cleveland ore which passed Lloyd's tests, and the materials of which the steel was composed was a most important matter for them to consider. With the early basic steel that was so unsatisfactory, they used an ore containing 3 per cent. of phosphorus, but the good angles to which reference had been made were made from ore containing only 1.5 per cent. of phosphorus, and the question therefore arose whether good steel could be only made on this process with an ore containing little phosphorus. Objection had been raised that Lloyd's had accepted steel made on the basic process abroad, whilst they would not pass British-made basic steel. His answer was, firstly, that Lloyd's were a foreign as well as a British registry, and they classed foreign-built ships, and therefore they had to have surveyors abroad and accept foreign materials if suitable. The foreign basic steel was suitable. It was made in the open-hearth furnace, and not the converter, from an ore containing a small percentage of phosphorus, and, moreover, a very large quantity of scrap was used. This was a very different thing from that which the northeast

## TABLE I.—Experiments Made in 1887 on Basic Bessemer Steel (Sleeper Quality).

| Description of Steel. | Distinguishing Number. | Plate. Thickness before Testing. | Plate. Width before Testing. | Plate. Sectional Area before Testing. | Tensile Tests. Lengthwise or Across. | Tensile Tests. Breaking Stress in Tons. Actual Producing Rupture. | Tensile Tests. Breaking Stress in Tons. Per Square Inch of Area before Testing. | Tensile Tests. Extension in 8 Ins. | Temperature of Test-House in Degrees Fahrenheit. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|
| | blow. | in. | in. | sq. in. | | tons. | tons. | per cent. | | |
| Converter, | 379 | .39 | 1.51 | .588 | L. | 17.9 | 30.4 | 21 | | |
| " | 379 | .39 | 1.51 | .588 | A. | 17.8 | 30 3 | 21 | ... | Cold forge and temper tests, rough shorn, satisfactory. |
| " | 379 | .495 | 1.51 | .747 | L. | 23.1 | 30.9 | 19 | | |
| " | 379 | .50 | 1.51 | .755 | A. | 21.4 | 28.3 | 20 | | |
| " | 379 | .50 | 1 51 | .755 | L. | 21.8 | 28.9 | 23 | | |
| " | 379 | .50 | 1.51 | .755 | A. | 21.1 | 30.6 | 26 | | |
| | | | | | *The following samples were tested after annealing:* | | | | | |
| " | 379 | .39 | 1.51 | .588 | L. | 16.5 | 28.0 | 26 | | |
| " | 379 | .385 | 1 51 | .581 | A. | 16 3 | 28.1 | 16 | | |
| " | 379 | .50 | 1.51 | .755 | L. | 20.0 | 26.5 | 29 | | |
| " | 379 | .50 | 1.51 | .755 | A. | 21.3 | 28.2 | 25 | | |

## TABLE III.—Experiments Made at Pembroke Dockyard in 1888, on Basic Bessemer Steel.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Converter, | 1 | .49 | 2.09 | 1.024 | ... | 27 9 | 27.2 | 29 5 | 60 | Unperforated plate. |
| " | 2 | 49 | 2.11 | 1.033 | ... | 27.2 | 26.4 | 32.0 | 60 | |
| " | 3 | 49 | 2.07 | 1.014 | ... | 29.2 | 28.8 | 28.7 | 60 | |
| " | 4 | .49 | 2.0 | .98 | ... | 29.1 | 29.7 | 27.9 | 60 | |
| " | 5 | .49 | 3.44 | 1.685 | ... | 38.5 | 22.9 | ... | 60 | Holes punched 7/8 in. before shaping. See Fig. 1. |
| " | 6 | .49 | 3.42 | 1.675 | ... | 36.8 | 22.0 | ... | 60 | |
| " | 7 | .49 | 3 15 | 1.543 | ... | 46.9 | 30.4 | ... | 60 | Holes drilled 7/8 in., countersunk right through plate. See Fig. 1. |
| " | 8 | 50 | 3.13 | 1 565 | ... | 47.2 | 30.2 | ... | 60 | |
| " | 9 | .50 | 3.22 | 1 61 | ... | 44.6 | 27 7 | ... | 60 | Holes punched 3/4 in. before shaping, countersunk to 7/8 in. See Fig. 1. |
| " | 10 | .505 | 3.21 | 1 621 | ... | 48.5 | 29.9 | ... | 60 | |
| " | 13 | .50 | 3.43 | 1.715 | ... | 52 9 | 30.8 | ... | 60 | Holes drilled 7/8 in. See Fig. 1. |
| " | 14 | .50 | 3.43 | 1.715 | ... | 52 4 | 30.6 | ... | 60 | |

## TABLE V.—Experiments Made at Pembroke Dockyard in 1889, on Basic Open-Hearth Steel.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Open hearth, | 1 | .45 | 1.98 | .891 | L. | 21.5 | 24.1 | 27.5 | 58 | No. 2 broke outside center marks. Unperforated plate. |
| " | 2 | .45 | 1.98 | .891 | L. | 21.5 | 24.1 | ... | 58 | |
| " | 3 | .47 | 1.98 | .931 | A | 22.9 | 24.7 | 30 0 | 58 | |
| " | 4 | .47 | 1.98 | .931 | A. | 23 2 | 24 9 | 28.7 | 58 | |
| " | 5 | .47 | 3.20 | 1.504 | ... | 35.7 | 23.7 | ... | 58 | Holes punched 7/8 in. before shaping. See Fig. 1. |
| " | 6 | .47 | 3 20 | 1.504 | ... | 32.8 | 21.8 | ... | 58 | |
| " | 7 | .47 | 3 20 | 1.504 | ... | 30 6 | 20 3 | ... | 58 | Holes punched 7/8 in. after shaping. See Fig. 1. |
| " | 8 | .47 | 3.20 | 1.504 | ... | 31.7 | 21.1 | ... | 58 | |
| " | 9 | .46 | 2.95 | 1 357 | ... | 34 6 | 25.5 | ... | 58 | Holes drilled 7/8 in. and countersunk through. |
| " | 10 | .46 | 2.95 | 1.357 | ... | 37.2 | 27.4 | ... | 58 | |
| " | 11 | .46 | 3.12 | 1.435 | ... | 40.0 | 27 9 | ... | 58 | Holes punched 3/4 in. and countersunk to 7/8 in. See Fig 1. |
| " | 12 | 45 | 3.12 | 1.404 | ... | 32.4 | 23.1 | ... | 58 | |
| " | 13 | 46 | 3.35 | 1 541 | ... | 39.2 | 25.5 | ... | 58 | Holes drilled 7/8 in. See Fig. 1. |
| " | 14 | .46 | 3.35 | 1.541 | ... | 41.2 | 26.7 | ... | 58 | |

NOTE.—Test pieces from No. 1 of Table V to No. 22 of Table VI (except Nos. 5, 6, 7, 8,) were made from the same plate.

NOTE.—Test pieces from No. 1 of Table V to No. 22 of Table VI (except Nos. 5, 6, 7, 8,) were made from the same plate.

**TABLE VII.—Experiments Made at Pembroke Dockyard in 1890, on Basic Open-Hearth Steel.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Open hearth, | 1 | .47 | 2.21 | 1.039 | L. | ... | ... | ... | 60 | No. 1 broke in the grip. |
| " | 2 | .48 | 2.21 | 1.001 | L. | 26.3 | 24.8 | 23.1 | 60 | Unperforated plate. |
| " | 3 | .47 | 2.22 | 1.043 | A. | 27.5 | 26.3 | ... | 60 | No. 3 broke outside centers. |
| " | 4 | .47 | 2.22 | 1.043 | A. | 27.5 | 26.3 | 20.0 | 60 | |
| " | 5 | .49 | 3.42 | 1.676 | ... | 42.9 | 25.6 | ... | 60 | Holes punched ⅞ in. before shaping. See Fig. 1. |
| " | 6 | .49 | 3.42 | 1.676 | ... | 43.3 | 25.8 | ... | 60 | |
| " | 7 | .49 | 3.37 | 1.651 | ... | 43.7 | 26.5 | ... | 60 | Holes punched ⅞ in. after shaping. See Fig. 1. |
| " | 8 | .49 | 3.42 | 1.676 | ... | 43.1 | 25.7 | ... | 60 | |
| " | 9 | .49 | 3.19 | 1.563 | ... | 45.8 | 29.3 | ... | 60 | Holes drilled ⅞ in. and countersunk through. See Fig. 1. |
| " | 10 | .49 | 3.14 | 1.539 | ... | 49.5 | 32.2 | ... | 60 | |
| " | 11 | .49 | 3.11 | 1.524 | ... | 44.0 | 28.8 | ... | 60 | Holes punched ¾ in. and countersunk to ⅞ in. See Fig. 1. |
| " | 12 | .49 | 3.17 | 1.553 | ... | 44.6 | 28.7 | ... | 60 | |
| " | 13 | .50 | 3.43 | 1.715 | ... | 52.7 | 30.7 | ... | 60 | Holes drilled ⅞ in. See Fig. 1. |
| " | 14 | .50 | 3.43 | 1.715 | ... | 51.3 | 29.9 | ... | 60 | |

**TABLE IX.—Experiments Made at Pembroke Dockyard in 1890, on Basic Open-Hearth Steel.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Open hearth, | 1 | .49 | 2.29 | 1.088 | L. | 28.1 | 25.8 | 31.2 | 66 | Unperforated plate. |
| " | 2 | .49 | 2.22 | 1.088 | L. | 27.9 | 25.6 | 32.5 | 66 | |
| " | 3 | .48 | 2.24 | 1.075 | A. | 26.2 | 24.3 | 26.2 | 66 | |
| " | 4 | .48 | 2.23 | 1.070 | A. | 26.1 | 24.4 | 26.2 | 66 | |
| " | 5 | .49 | 3.36 | 1.646 | ... | 42.2 | 25.6 | ... | 66 | Holes punched ⅞ in. before shaping. See Fig. 1. |
| " | 6 | .49 | 3.36 | 1.646 | ... | 43.1 | 26.2 | ... | 66 | |
| " | 7 | .49 | 3.29 | 1.612 | ... | 41.7 | 25.9 | ... | 66 | Holes punched ⅞ in. after shaping. See Fig. 1. |
| " | 8 | .49 | 3.29 | 1.612 | ... | 41.7 | 25.9 | ... | 66 | |
| " | 9 | .49 | 2.78 | 1.362 | ... | 38.4 | 28.2 | ... | 66 | Holes drilled ⅞ in. and countersunk through. See Fig. 1. |
| " | 10 | .49 | 2.78 | 1.362 | ... | 36.2 | 26.5 | ... | 66 | |
| " | 11 | .49 | 2.93 | 1.436 | ... | 39.1 | 27.2 | ... | 66 | Holes punched ¾ in. and countersunk to ⅞ in. See Fig. 1. |
| " | 12 | .49 | 2.93 | 1.436 | ... | 38.3 | 26.7 | ... | 66 | |
| " | 13 | .49 | 3.48 | 1.705 | ... | 48.4 | 28.4 | ... | 66 | Holes drilled ⅞ in. See Fig. 1. |
| " | 14 | .49 | 3.48 | 1.705 | ... | 48.4 | 28.4 | ... | 66 | |

**TABLE XI.—Experiments Made at Pembroke Dockyard in 1890, on Basic Open-Hearth Steel.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Open hearth, | 1 | .47 | 2.2 | 1.034 | L. | 32.4 | 31.3 | 25 | 70 | Unperforated plate. |
| " | 2 | .47 | 2.2 | 1.034 | L. | 32.4 | 31.3 | 26.2 | 70 | |
| " | 3 | .47 | 2.21 | 1.039 | A. | 32.8 | 31.5 | 20.0 | 70 | |
| " | 4 | .47 | 2.21 | 1.039 | A. | 32.1 | 30.9 | ... | 70 | No. 4. broke outside centers. |
| " | 5 | .47 | 3.4 | 1.598 | ... | 46.0 | 28.8 | ... | 70 | Holes punched ⅞ in. before shaping. See Fig. 1. |
| " | 6 | .47 | 3.4 | 1.598 | ... | 47.8 | 29.9 | ... | 70 | |
| " | 7 | .47 | 3.4 | 1.598 | ... | 47.3 | 29.6 | ... | 70 | Holes punched ⅞ in. after shaping. See Fig. 1. |
| " | 8 | .47 | 3.4 | 1.598 | ... | 49.1 | 30.7 | ... | 70 | |
| " | 9 | .47 | 3.11 | 1.462 | ... | 46.4 | 31.8 | ... | 70 | Holes drilled ⅞ in. and countersunk through. See Fig. 1. |
| " | 10 | .47 | 3.11 | 1.462 | ... | 46.9 | 32.1 | ... | 70 | |
| " | 11 | .47 | 3.1 | 1.457 | ... | 48.2 | 33.1 | ... | 70 | Holes punched ¾ in. and countersunk to ⅞ in. See Fig. 1. |
| " | 12 | .47 | 3.1 | 1.457 | ... | 48.2 | 33.1 | ... | 70 | |
| " | 13 | .48 | 3.4 | 1.632 | ... | 52.7 | 32.3 | ... | 70 | Holes drilled ⅞ in. See Fig. 1. |
| " | 14 | .48 | 3.4 | 1.632 | ... | 51.8 | 31.7 | ... | 70 | |

**TABLE XIII.—Experiments Made at Pembroke Dockyard in 1891, on Basic Open-Hearth Steel.**

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Open hearth, | 1 | .47 | 2.25 | 1.057 | L. | 29.0 | 27.4 | 27.5 | 66 | Unperforated plate. |
| " | 2 | .47 | 2.22 | 1.043 | L. | 29.1 | 27.9 | 26.9 | 66 | |
| " | 3 | .48 | 2.24 | .075 | A. | 29.7 | 27.6 | 25.0 | 66 | |
| " | 4 | .48 | 2.22 | 1.066 | A. | 29.5 | 27.6 | 23.7 | 66 | |
| " | 5 | .47 | 3.40 | 1.598 | ... | 39.1 | 24.4 | ... | 66 | Holes punched ⅞ in. before shaping. See Fig. 1. |
| " | 6 | .47 | 3.40 | 1.598 | ... | 39.7 | 24.9 | ... | 66 | |
| " | 7 | .47 | 3.40 | 1.598 | ... | 39.2 | 24.5 | ... | 66 | Holes punched ⅞ in. after shaping. See Fig. 1. |
| " | 8 | .47 | 3.40 | 1.598 | ... | 38.2 | 23.9 | ... | 66 | |
| " | 10 | .47 | 3.07 | 1.443 | ... | 41.7 | 28.9 | ... | 66 | Holes drilled ⅞ in. and countersunk through. See Fig. 1. |
| " | 11 | .47 | 3.14 | 1.476 | ... | 40.8 | 27.7 | ... | 66 | Holes punched ¾ in. and countersunk to ⅞ in. See Fig. 1. |
| " | 12 | .46 | 3.18 | 1.463 | ... | 40.8 | 27.9 | ... | 66 | |
| " | 13 | .46 | 3.37 | 1.550 | ... | 43.5 | 28.1 | ... | 66 | Holes drilled ⅞ in. See Fig. 1. |
| " | 14 | .47 | 3.37 | 1.584 | ... | 44.0 | 27.8 | ... | 66 | |

**TABLE II.—Experiments Made in 1887, to Ascertain the Effect of Riveting on Basic Bessemer Steel (Sleeper Quality).**

| Description of Steel. | Distinguishing Number. | Nature of Joint. | Plate. | | | Riveting. | | | Mode of Fracture. | Breaking Stress in Tons. | | | Temperature of Test-House in Degrees Fahr. | Remarks. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Thickness before Testing. | Width before Testing (Net). | Sectional Area before Testing (Net). | Nature. | Diameter of Rivet. | Pitch of Rivet. | | Actual Producing Rupture. | Per Square Inch. | | | |
| | | | | | | | | | | | Of Area before Testing. | Mean Results. | | |
| | | | in. | in. | sq. in. | | in. | dia. | | tons. | tons. | tons. | | |
| Converter, | $A_1$ | Double-riveted lapped joint with shorn edges. | ½ | 4¼ | 2⅜ | Pan heads, countersunk points. | ¾ | 4½ | Rivets, 4 No., sheared. | 45.6 | | | | |
| " | $A_2$ | do. with planed edges. | ½ | 4¾ | 2⅜ | " | ¾ | 4½ | " | 42.4 | | | | |
| | $A_3$ | " | ½ | 4¾ | 2⅜ | " | ¾ | 4½ | " | 45.8 | | | | |
| " | $B_1$ | Single-riveted, single-strapped butt, with planed edges. | ½ | ... | 1.54 | " | ¾ | 2 | Plate broke across holes. | 37.8 | 24.5 | 23.6 | | |
| | $B_2$ | " | ½ | ... | 1.54 | " | ¾ | 2 | " | 35.0 | 22.7 | | | |
| " | $C_1$ | " | ½ | 4¾ | 2⅜ | " | ¾ | 4½ | Rivets, 2 No., sheared. | 23.9 | | | | |
| | $C_2$ | " | ½ | 4¾ | 2⅜ | " | ¾ | 4½ | " | 25.6 | | | | |
| " | $D_1$ | Double-riveted, single-strapped butt, with planed edges. | ½ | 4¾ | 2⅜ | " | ¾ | 4½ | Rivets, 4 No., sheared. | 45.5 | | | | |
| | $D_2$ | " | ½ | 4¾ | 2.4 | " | ¾ | 4½ | " | 45.9 | | | | |
| | $E_1$ | Treble-riveted, single-strapped butt, with planed edges. | ½ | ... | 2.4 | " | ¾ | 4½ | Plate broke across outside row of rivets. | 66.1 | 27.5 | 26.7 | | |
| | $E_2$ | " | ½ | ... | ... | " | ¾ | 4½ | " | 62.4 | 26.0 | | | |
| " | $F_1$ | Treble-riveted, single-strapped butt, with diamond-shaped butt straps. | ½ | ... | ... | " | ¾ | 3 | Rivets, 6 No., sheared. | 65.1 | | | | |
| | $F_2$ | " | ½ | ... | ... | " | ¾ | 3 | " | | | | | |
| | $G_1$ | Double-riveted, double-strapped butt, with alternate rivets omitted in outside row. | ⅜ | ... | ... | Pan heads, snap points. | ¾ | 3 | Plate broke at holes. | 67.1 | ... | ... | ... | Irregular fracture. |
| " | $G_2$ | " | ⅜ | ... | ... | " | ¾ | 3 | " | ... | ... | ... | ... | " |

**TABLE IV.—Experiments Made at Pembroke Dockyard in 1888, to Ascertain the Effect of Riveting on Basic Bessemer Steel.**

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Converter, | 15 | Double-riveted, single-strapped butt. See Fig. 2. | .5 | 2.33 | 1.165 | Pan heads, countersunk points. | ¾ | ... | Butt strap broke. | ... | 18.5 | ... | 70 |
| " | 16 | " | .5 | 2.39 | 1.195 | " | ¾ | ... | Plate broke. | 35.6 | 29.8 | .. | 70 |
| " | 17 | " | .48 | 2.65 | 1.272 | Pan heads, snap points. | ¾ | ... | " | 27.8 | 21.9 | ... | 70 |
| " | 18 | " | .48 | 2.61 | 1.252 | " | ¾ | ... | Butt strap broke. | ... | 15.7 | ... | 70 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| " | 18 | " | .48 | 2.61 | 1.252 | " | ¾ | ... | Butt strap broke. | ... | 15.7 | ... | 70 | |
| " | 19 | " | .5 | 3.21 | 1.605 | Pan heads, countersunk points. | ⅞ | ... | " | ... | 25.7 | ... | 70 | |
| " | 20 | " | .5 | 3.21 | 1.605 | " | ⅞ | ... | " | ... | 25.7 | ... | 70 | |
| " | 21 | " | .5 | 3.49 | 1.745 | Pan heads, snap points. | ⅞ | ... | " | ... | 17.1 | ... | 70 | |
| " | 22 | " | .5 | 3.49 | 1 745 | " | ⅞ | ... | Plate broke. | 52.0 | 29.8 | ... | 70 | |
| " | 23 | Treble-riveted single-strapped butt. See Fig. 3. | .48 | 3.29 | 1.579 | " | ¾ | 3½ | " | 28.7 | 18.2 | 19.6 | 70 | |
| " | 24 | " | .5 | 3.28 | 1.64 | " | ¾ | 3½ | " | 34.4 | 21.0 | | | |
| " | 25 | " | .48 | 3.7 | 1.776 | " | ¾ | 4 | " | 35.6 | 20.1 | 17.9 | 70 | |
| " | 26 | " | .48 | 3.68 | 1.766 | " | ¾ | 4 | " | 27.8 | 15.7 | | | |
| " | 27 | " | .5 | 4.11 | 2.055 | " | ¾ | 4½ | " | 31.9 | 15.5 | 16.2 | 70 | |
| " | 28 | " | .5 | 4.1 | 2.05 | " | ¾ | 4½ | " | 34.8 | 17.0 | | | |

**TABLE VI.—Experiments Made at Pembroke Dockyard in 1889, to Ascertain the Effect of Riveting on Basic Open-Hearth Steel.**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Open hearth, | 15 | Double-riveted, single-strapped butt. See Fig. 2. | .48 | 2.45 | 1.176 | Pan heads, countersunk points. | ¾ | ... | Plate broke. | 33.4 | 28.4 | 28.8 | 62 | |
| " | 16 | " | .48 | 2.45 | 1.176 | " | ¾ | ... | " | 34.5 | 29.3 | | | |
| " | 17 | " | .48 | 2.77 | 1.33 | Pan heads, snap points. | ¾ | ... | " | 36.6 | 27.5 | 27.1 | 62 | |
| " | 18 | " | .48 | 2.77 | 1.33 | " | ¾ | ... | " | 35.6 | 26.8 | | | |
| " | 19 | " | .47 | 3.07 | 1.44 | Pan heads, countersunk points. | ⅞ | ... | Butt strap broke. | ... | ... | ... | 62 | Irregular fracture. |
| " | 20 | " | .46 | 3.07 | 1.41 | " | ⅞ | ... | Plate broke. | 40.6 | 28 8 | ... | 62 | |
| " | 21 | " | .46 | 3.37 | 1.55 | Pan heads, snap points. | ⅞ | ... | " | 44 4 | 28.6 | 29.4 | 62 | |
| " | 22 | " | .46 | 3.37 | 1.55 | " | ⅞ | ... | " | 46.8 | 30.2 | | | |
| " | 23 | Treble-riveted single-strapped butt. See Fig. 3. | .46 | 3.34 | 1.536 | " | ¾ | 3½ | " | 34.0 | 22.2 | 24.1 | 62 | All plates punched, butt straps drilled. |
| " | 24 | " | .46 | 3.34 | 1.536 | " | ¾ | 3½ | " | 39 7 | 25.9 | | | |
| " | 25 | " | .46 | 3.78 | 1.74 | " | ¾ | 4 | " | 38.7 | 22.2 | 21.8 | 62 | |
| " | 26 | " | .46 | 3.78 | 1.74 | " | ¾ | 4 | " | 37.3 | 21.4 | | | |
| " | 27 | " | .46 | 4.15 | 1.91 | " | ¾ | 4½ | " | 27.9 | 14.6 | 16.9 | 62 | |
| " | 28 | " | .46 | 4.15 | 1.91 | " | ¾ | 4½ | " | 36.8 | 19.3 | | | |

**TABLE VIII.—Experiments Made at Pembroke Dockyard in 1890, to Ascertain the Effect of Riveting on Basic Open-Hearth Steel.**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Open hearth, | 15 | Double-riveted, single-strapped butt. See Fig. 2. | .50 | 2.42 | 1.21 | Pan heads, countersunk points. | ¾ | ... | Plate broke. | 35.0 | 29.0 | 28.9 | 62 | |
| " | 16 | " | .50 | 2.42 | 1.21 | " | ¾ | ... | " | 34.8 | 28.8 | | | |
| " | 17 | " | .50 | 2.68 | 1.34 | Pan heads, snap points. | ¾ | ... | " | 39.5 | 29.5 | 29.3 | 62 | |
| " | 18 | " | .50 | 2.68 | 1.34 | " | ¾ | ... | " | 39.1 | 29.1 | | | |
| " | 19 | " | .48 | 3.13 | 1.502 | Pan heads, countersunk points. | ⅞ | ... | " | 45.8 | 30.4 | 30.4 | 62 | |
| " | 20 | " | .48 | 3.13 | 1.502 | " | ⅞ | ... | " | 45.8 | 30.4 | | | All plates punched, butt straps drilled. |
| " | 21 | " | .48 | 3.38 | 1.622 | Pan heads, snap points. | ⅞ | ... | " | 45.6 | 28.1 | 28.3 | 62 | |
| " | 22 | " | .48 | 3.38 | 1.622 | " | ⅞ | ... | " | 46.4 | 28.6 | | | |
| " | 23 | Treble-riveted, single-strapped butt. See Fig. 3. | .51 | 3.23 | 1.647 | " | ¾ | 3½ | " | 48.0 | 29.1 | 29.8 | 62 | |
| " | 24 | " | .51 | 3.23 | 1.647 | " | ¾ | 3½ | " | 50 4 | 30.6 | | | |
| " | 25 | " | .51 | 3.45 | 1.76 | " | ¾ | 4 | " | 48.2 | 27.4 | 28.0 | 62 | |
| " | 26 | " | .51 | 3.45 | 1.76 | " | ¾ | 4 | " | 50.3 | 28.6 | | | |
| " | 27 | " | .51 | 3.99 | 2.035 | " | ¾ | 4½ | " | 55.4 | 27.2 | 27.6 | 62 | |
| " | 28 | " | .51 | 3.99 | 2.035 | " | ¾ | 4½ | " | 57.1 | 28.1 | | | |

**TABLE X.—Experiments Made at Pembroke Dockyard in 1890, to Ascertain the Effect of Riveting on Basic Open-Hearth Steel.**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Open hearth, | 15 | Double-riveted, single-strapped butt. See Fig. 2. | .49 | 2.32 | 1.137 | Pan heads, countersunk points. | ¾ | ... | Plate broke. | 29.7 | 26.1 | 26.2 | 66 | |
| " | 16 | " | .49 | 2.32 | 1.137 | " | ¾ | ... | " | 29.9 | 26.3 | | | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | butt. See Fig. 3. | | | | | | | | | | | | |
| " | 24 | " | .5 | 3.28 | 1.64 | " | ¾ | 3½ | " | 34.4 | 21.0 | | | |
| " | 25 | " | .48 | 3.7 | 1.776 | " | ¾ | 4 | " | 35.6 | 20.1 | 17.9 | 70 | |
| " | 26 | " | .48 | 3.68 | 1.766 | " | ¾ | 4 | " | 27.8 | 15.7 | | | |
| " | 27 | " | .5 | 4.11 | 2.055 | " | ¾ | 4½ | " | 31.9 | 15.5 | 16.2 | 70 | |
| " | 28 | " | .5 | 4.1 | 2.05 | " | ¾ | 4½ | " | 34.8 | 17.0 | | | |

**TABLE VI.—Experiments Made at Pembroke Dockyard in 1889, to Ascertain the Effect of Riveting on Basic Open-Hearth Steel.**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Open hearth, | 15 | Double-riveted, single-strapped butt. See Fig. 2. | .48 | 2.45 | 1.176 | Pan heads, countersunk points. | ¾ | ... | Plate broke. | 33.4 | 28.4 | 28.8 | 62 | |
| " | 16 | " | .48 | 2.45 | 1.176 | " | ¾ | ... | " | 34.5 | 29.3 | | | |
| " | 17 | " | .48 | 2.77 | 1.33 | Pan heads, snap points. | ¾ | ... | " | 36.6 | 27.5 | 27.1 | 62 | |
| " | 18 | " | .48 | 2.77 | 1.33 | " | ¾ | ... | " | 35.6 | 26.8 | | | |
| " | 19 | " | .47 | 3.07 | 1.44 | Pan heads, countersunk points. | ⅞ | ... | Butt strap broke. | ... | ... | ... | 62 | Irregular fracture. |
| " | 20 | " | .46 | 3.07 | 1.41 | " | ⅞ | ... | Plate broke. | 40.6 | 28.8 | ... | 62 | |
| " | 21 | " | .46 | 3.37 | 1.55 | Pan heads, snap points. | ⅞ | ... | " | 44.4 | 28.6 | 29.4 | 62 | |
| " | 22 | " | .46 | 3.37 | 1.55 | " | ⅞ | ... | " | 46.8 | 30.2 | | | |
| " | 23 | Treble-riveted single-strapped butt. See Fig. 3. | .46 | 3.34 | 1.536 | " | ¾ | 3½ | " | 34.0 | 22.2 | 24.1 | 62 | All plates punched, butt straps drilled. |
| " | 24 | " | .46 | 3.34 | 1.536 | " | ¾ | 3½ | " | 39.7 | 25.9 | | | |
| " | 25 | " | .46 | 3.78 | 1.74 | " | ¾ | 4 | " | 38.7 | 22.2 | 21.8 | 62 | |
| " | 26 | " | .46 | 3.78 | 1.74 | " | ¾ | 4 | " | 37.3 | 21.4 | | | |
| " | 27 | " | .46 | 4.15 | 1.91 | " | ¾ | 4½ | " | 27.9 | 14.6 | 16.9 | 62 | |
| " | 28 | " | .46 | 4.15 | 1.91 | " | ¾ | 4½ | " | 36.8 | 19.3 | | | |

**TABLE VIII.—Experiments Made at Pembroke Dockyard in 1890, to Ascertain the Effect of Riveting on Basic Open-Hearth Steel.**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Open hearth, | 15 | Double-riveted, single-strapped butt. See Fig. 2. | .50 | 2.42 | 1.21 | Pan heads, countersunk points. | ¾ | ... | Plate broke. | 35.0 | 29.0 | 28.9 | 62 | |
| " | 16 | " | .50 | 2.42 | 1.21 | " | ¾ | ... | " | 34.8 | 28.8 | | | |
| " | 17 | " | .50 | 2.68 | 1.34 | Pan heads, snap points. | ¾ | ... | " | 39.5 | 29.5 | 29.3 | 62 | |
| " | 18 | " | .50 | 2.68 | 1.34 | " | ¾ | ... | " | 39.1 | 29.1 | | | |
| " | 19 | " | .48 | 3.13 | 1.502 | Pan heads, countersunk points. | ⅞ | ... | " | 45.8 | 30.4 | 30.4 | 62 | |
| " | 20 | " | .48 | 3.13 | 1.502 | " | ⅞ | ... | " | 45.8 | 30.4 | | | All plates punched, butt straps drilled. |
| " | 21 | " | .48 | 3.38 | 1.622 | Pan heads, snap points. | ⅞ | ... | " | 45.6 | 28.1 | 28.3 | 62 | |
| " | 22 | " | .48 | 3.38 | 1.622 | " | ⅞ | ... | " | 46.4 | 28.6 | | | |
| " | 23 | Treble-riveted, single-strapped butt. See Fig. 3. | .51 | 3.23 | 1.647 | " | ¾ | 3½ | " | 48.0 | 29.1 | 29.8 | 62 | |
| " | 24 | " | .51 | 3.23 | 1.647 | " | ¾ | 3½ | " | 50.4 | 30.6 | | | |
| " | 25 | " | .51 | 3.45 | 1.76 | " | ¾ | 4 | " | 48.2 | 27.4 | 28.0 | 62 | |
| " | 26 | " | .51 | 3.45 | 1.76 | " | ¾ | 4 | " | 50.3 | 28.6 | | | |
| " | 27 | " | .51 | 3.99 | 2.035 | " | ¾ | 4½ | " | 55.4 | 27.2 | 27.6 | 62 | |
| " | 28 | " | .51 | 3.99 | 2.035 | " | ¾ | 4½ | " | 57.1 | 28.1 | | | |

**TABLE X.—Experiments Made at Pembroke Dockyard in 1890, to Ascertain the Effect of Riveting on Basic Open-Hearth Steel.**

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Open hearth, | 15 | Double-riveted, single-strapped butt. See Fig. 2. | .49 | 2.32 | 1.137 | Pan heads, countersunk points. | ¾ | ... | Plate broke. | 29.7 | 26.1 | 26.2 | 66 | |
| " | 16 | " | .49 | 2.32 | 1.137 | " | ¾ | ... | " | 29.9 | 26.3 | | | |
| " | 17 | " | .49 | 2.59 | 1.269 | Pan heads, snap points. | ¾ | ... | Butt strap broke. | ... | 29.4 | ... | 66 | |
| " | 18 | " | .49 | 2.59 | 1.269 | " | ¾ | ... | " | ... | 28.9 | ... | 66 | |
| " | 19 | " | .49 | 3.18 | 1.558 | Pan heads, countersunk points. | ⅞ | ... | Plate broke. | 43.1 | 27.6 | 27.8 | 66 | |
| " | 20 | " | .49 | 3.18 | 1.558 | " | ⅞ | ... | " | 43.7 | 28.1 | | | All plates punched, butt straps drilled. |
| " | 21 | " | .49 | 3.43 | 1.681 | Pan heads, snap points. | ⅞ | ... | " | 49.3 | 29.3 | 29.0 | 66 | |
| " | 22 | " | .49 | 3.43 | 1.681 | " | ¾ | ... | " | 48.2 | 28.7 | | | |

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | snap points. | | | | | | | 29.0 | 66 | butt straps drilled. |
| " | 22 | " | .49 | 3.43 | 1.681 | " | ⅞ | ... | " | 48.2 | 28.7 | | | | |
| " | 23 | Treble-riveted, single-strapped butt. See Fig. 3. | .48 | 3.21 | 1.541 | " | ¾ | 3½ | Butt strap broke. | ... | 28.8 | ... | 66 | | |
| " | 24 | " | .48 | 3.21 | 1.541 | " | ¾ | 3½ | " | ... | 29.0 | ... | 66 | | |
| " | 25 | " | .48 | 3.61 | 1.733 | " | ¾ | 4 | " | ... | 27.4 | ... | 66 | | |
| " | 26 | " | .48 | 3.61 | 1.733 | " | ¾ | 4 | Plate broke. | 49.0 | 28.3 | ... | 66 | | |
| " | 27 | " | .48 | 3.98 | 1.910 | " | ¾ | 4½ | Butt strap broke. | ... | 27.6 | ... | 66 | | |
| " | 28 | " | .48 | 3.98 | 1.910 | " | ¾ | 4½ | " | ... | 27.4 | ... | 66 | | |

**TABLE XII.—Experiments Made at Pembroke Dockyard in 1890, to Ascertain the Effect of Riveting on Basic Open-Hearth Steel.**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Open hearth, | 15 | Double-riveted, single-strapped butt. See Fig. 2. | .48 | 2.28 | 1.094 | Pan heads, countersunk points. | ¾ | ... | Plate broke. | 36.4 | 33.2 | 32.8 | 70 | | |
| " | 16 | " | .48 | 2.28 | 1.094 | " | ¾ | ... | " | 35.5 | 32.4 | | | | |
| " | 17 | " | .48 | 2.55 | 1.224 | Pan heads, snap points. | ¾ | ... | " | 35.7 | 29.2 | | | | |
| " | 18 | " | .48 | 2.55 | 1.224 | " | ¾ | ... | " | 35.7 | 29.2 | 29.2 | 70 | | |
| " | 19 | " | .47 | 3.08 | 1.448 | Pan heads, countersunk points. | ⅞ | ... | " | 47.1 | 32.5 | 32.3 | 70 | | |
| " | 20 | " | .47 | 3.08 | 1.448 | " | ⅞ | ... | " | 46.4 | 32.1 | | | | All plates punched, butt straps drilled. |
| " | 21 | " | .47 | 3.33 | 1.565 | Pan heads, snap points. | ⅞ | ... | " | 48.7 | 31.1 | | | | |
| " | 22 | " | .47 | 3.33 | 1.565 | " | ⅞ | ... | " | 50.9 | 32.5 | 31.8 | 70 | | |
| " | 23 | Treble-riveted, single-strapped butt. See Fig. 3. | .47 | 3 19 | ..499 | " | ¾ | 3½ | " | 47.8 | 31 8 | 31.8 | 70 | | |
| " | 24 | " | .48 | 3.19 | 1.531 | " | ¾ | 3½ | " | 48.7 | 31.8 | | | | |
| " | 25 | " | .47 | 3.68 | 1.73 | " | ¾ | 4 | " | 52.0 | 30.1 | | | | |
| " | 26 | " | .465 | 3.68 | 1.711 | " | ¾ | 4 | " | 53.1 | 31 0 | 30.5 | 70 | | |
| " | 27 | " | .47 | 3.89 | 1.828 | " | ¾ | 4½ | " | 56.5 | 30.9 | | | | |
| " | 28 | " | .47 | 3.89 | 1.828 | " | ¾ | 4½ | " | 55.8 | 30.5 | 30.7 | 70 | | |

**TABLE XIV.—Experiments Made at Pembroke Dockyard in 1891, to Ascertain the Effect of Riveting on Basic Open-Hearth Steel.**

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Open hearth, | 15 | Double-riveted single-strapped butt. See Fig. 2. | .46 | 2.30 | 1.058 | Pan heads, countersunk points. | ¾ | ... | Plate broke. | 31.7 | 30.0 | 30.5 | 64 | | |
| " | 16 | " | .47 | 2.30 | 1.081 | " | ¾ | ... | " | 33.5 | 31.0 | | | | |
| " | 17 | " | .47 | 2.56 | 1.203 | Pan heads, snap points. | ¾ | ... | " | 39.3 | 32.6 | 32.5 | 64 | | |
| " | 18 | " | .46 | 2.56 | 1,178 | " | ¾ | ... | " | 38.2 | 32.4 | | | | |
| " | 19 | " | .46 | 3.12 | 1.435 | Pan heads, countersunk points. | ⅞ | ... | " | 42 0 | 29.2 | 28.6 | 64 | | |
| " | 20 | " | .47 | 3.12 | 1.466 | " | ⅞ | ... | " | 41.1 | 28.0 | | | | All plates punched, butt straps drilled. |
| " | 21 | " | .47 | 3.38 | 1.589 | Pan heads, snap points. | ⅞ | ... | " | 46.9 | 29.5 | 28.8 | 64 | | |
| " | 22 | " | .47 | 3.38 | 1.589 | " | ⅞ | ... | " | 44.9 | 28.2 | | 66 | | |
| " | 23 | Treble-riveted, single-strapped butt. See Fig. 3. | .46 | 3.24 | 1.490 | " | ¾ | 3½ | " | 48.2 | 32.3 | 31.1 | 66 | | |
| " | 24 | " | .47 | 3.24 | 1.523 | " | ¾ | 3½ | " | 45.8 | 30.0 | | | | |
| " | 25 | " | .46 | 3.67 | 1.688 | " | ¾ | 4 | " | 52.0 | 30.8 | 31.0 | 66 | | |
| " | 26 | " | .46 | 3.67 | 1.688 | " | ¾ | 4 | " | 52.7 | 31 2 | | | | |
| " | 27 | " | .47 | 4.08 | 1.918 | " | ¾ | 4½ | " | 54.5 | 28.4 | 29.1 | 66 | | |
| " | 28 | " | .47 | 4.08 | 1.918 | " | ¾ | 4½ | " | 57.1 | 29.8 | | | | |

coast would have them accept as basic steel, which was made from an ore with much phosphorus.

Sir Lowthian Bell said that the pig in his district had 1½ to 1¾ per cent. of phosphorus, and therefore was not the same as that mentioned by Mr. Martell, which was said to contain 3 per cent. of phosphorus. He would be very glad, however, if it did contain 3 per cent., as they could then take the phosphorus from the pig, where it was not wanted, and put it on the land where it was wanted. It was not difficult to get large quantities of phosphorus out of the bath, but it was the last amount that was so difficult to remove, and it was there that the value of the basic process came in. In the experimental works which had been erected by the speaker's firm they had reduced the percentage of phosphorus to 0.02 per cent., using pig from Cleveland ore. He did not despair of using Cleveland pig for steel-making, and that the product would equal any steel made by the acid process. Sir Lowthian congratulated the Institute in having Mr. Martell present at their meetings, and he congratulated Lloyd's too. It was good for both; but he never expected, in his most sanguine moments, that the Institute would be honored by a paper from so distinguished an official as Mr. White. Remarks had been made as to the Government keeping matters to themselves. That complaint was not without foundation in times past. He well remembered the Committee on Armor Plates which sat some years ago. It accumulated a great deal of information from various sources which would have been of great value to ironmakers. He had thought that the most natural thing to do to render this of use would be to inform the ironmakers what had been ascertained. He had accordingly made application for a copy of the official publication containing the report of the committee, but had been met by a positive refusal. As more liberal counsels now appeared to prevail at Whitehall, he would ask Mr. White to use his good offices to get a copy of that report for the library of the Institute.

A speaker whose name did not transpire took exception to Mr. Martell's statement that steel had not been made from Cleveland ore that would stand the Lloyd's tests. As a matter

of fact thousands of tons of such steel had been made from Cleveland ore for the Indian State railways.

Mr. J. D. Ellis suggested that it would be a good thing if the merits of various steels could be referred to without comparing one with another. His experience was entirely in favor of basic Bessemer, but some speakers preferred open-hearth. Mr. White, in his paper, had made reference to the manufacture of certain boiler tubes, and said that for their manufacture basic open-hearth steel was already admitted by the Admiralty. The speaker wondered if reference was here made to a peculiar description of boiler tube manufactured by John Brown & Co. He referred to the Serve tubes. These, as is well known, have internal ribs for the absorption of heat. The thickness of the metal was $\frac{1}{8}$ in. and the ribs stood up on the inside, radiating towards the axis of the tube to a distance of $\frac{1}{2}$ in. It would be easily understood that this construction required a metal of good quality, and basic Bessemer steel of 24 tons tensile strength, which was made at Mr. Arthur Cooper's works, was found to answer the purpose.

Mr. Wrightson remarked that more might have been said on the question of riveting. The author had remarked that with the milder qualities of basic steel there is practically no loss in punching, but the milder qualities are not so suitable for the Admiralty requirements as others. Mr. Wrightson thought that the use of basic steel depended very much upon these conditions. He could not speak with any authority upon shipbuilding, but he had had plenty of experience in bridge construction, and he was of opinion that the margin allowed should be more in the direction of ductility than in hardness. This was doubtless more important in bridges which were subject to percussive strains.

In replying to the discussion Mr. White said that he had not approached the subject of his paper altogether as a stranger, for a man who designs ships must know a little of a good many things, and among them was metallurgy, a science which he had studied under the late Dr. Percy. It had been his duty, when acting as assistant to Sir N. Barnaby, to visit most of the

large steel works in this country, and he gained a great deal of information in this way. Turning to another subject, he thought that for many years past the Admiralty could not have the charge of undue secrecy in scientific matters fairly brought home to them. The armor-plate committee sat twenty-five years ago, and he thought that any interest Sir Lowthian Bell would be likely now to take in the report would be entirely of an antiquarian nature. Sir N. Barnaby had given repeated proofs of his anxiety to make public matters of a nature likely to be useful to the shipbuilding and engineering industries of the country, by papers read both at that Institute and the Institution of Naval Architects; and the officers of the Admiralty were generally of opinion, and acted on that opinion, that nothing but good could come from an interchange of ideas between makers and users.

With regard to the different makes of steel, the attitude of the Admiralty was not that they desired to confine makers to either one method or another of steel making, so long as good results were obtained; but they had substantial reasons for determining not to use, for some purposes, converter steel made on the basic process; but they could use open-hearth steel. This had been their experience over and over again, and he therefore thought that they were justified in the position they had taken up. These remarks applied to the uses of the steel for riveting purposes. But if the steel makers will show that improvements in manufacture have removed the objectionable features, the Admiralty would be glad to reconsider their decision; for they dealt with products and not with processes. They did not ask officially what went into the furnace, but, as a matter of fact, they knew, for manufacturers never objected to tell, and trusted to their discretion in this matter. He was sorry that the position of the samples in relation to the axis of the ingot was not known. To get the information would be very difficult, and could only be done by the steel maker, and he could only deal with these matters as a user of plates, and in a broad and general manner. Mr. Martell had suggested an extension of the experiments to plates of greater substance, but in his Naval Architects' paper plates up to 1 in. in thickness had been dealt with. He asked

if the plates referred to by Mr. Martell were of open-hearth steel, to which question Mr. Martell answered in the affirmative. Mr. Snelus had referred to the strength of plates in the perforated parts, but this point was well understood, and had been dealt with very completely in the report of the Research Committee on Riveting, which had been presented to the Institution of Mechanical Engineers by Professor Kennedy.

Whether wright or wrong, shipbuilders think that they must punch plates. Engineers look on this as a brutal treatment, but the shipbuilders concluded that by countersinking right through they removed the ill effect of punching, and that was therefore their common practice. Mr. Wrightson had gone back to an early proposal, namely, to reduce the tensile strength of basic steel in favor of greater ductility. That might do for bridges, but a ship was a different thing. For ship construction stiffness was required, and stiffness was accompanied by tensile strength. It was for this reason the naval architects said that the tensile strength should not be lowered. When Mr. Riley was at Landore they came to the conclusion that a 35-ton steel could be used. Shipbuilders wanted stiffness; they did not want more ductility. When they had a metal that could be doubled up and bent over in the way the *Victoria's* bottom was, there was nothing left to be required in the way of ductility.—[The paper and discussion are reprinted from "Engineering."]

# XX.

# WHALEBACK STEAMERS.

By F. C. Goodall, Esq.

[Read at the Thirty-third Session of the Institution of Naval Architects, April 7th, 1892.]

I was induced to select this subject for a paper to be read at this Institution by reason that, since the visit to this country of the American whaleback steamer, the *Charles W. Wetmore*, I have frequently been consulted by shipowners and others as to my opinion of the efficiency, capabilities, and the probable future of this class of vessel as seagoing cargo boats.

As a preliminary remark, I desire to say that it is not my intention or object in this paper to lay before you any strong or advanced ideas of my own on this character of vessel, my plan being to give all the information I have been able to gather, and to analyze what the advantages and the disadvantages of whaleback steamers may be from a practical, theoretical and commercial standpoint; and, in addition, to form a comparison with the ordinary tramp steamer. I beg to assure you, at the same time, that I do not deprecate our existing style of cargo boat; neither do I wish to extol or unduly advocate the whaleback type of steamer at a time when we are still without practical experience of their performances on long sea voyages. But I am desirous of saying all that is possible on the most vital parts where a comparison can be drawn, so that there may be ample material for the discussion on this subject, on which mainly the importance of the present aspect of this question will hang. I feel assured that, if shipowners can see daylight through any reasonable scheme of reducing, without additional risk, the cost of carrying, they will gladly avail themselves of it, more particularly at the present time of low freights and keen competition.

The result of all the various great depressions in freights,

which we have seen through the last few decades, has been a number of vast improvements in steamship building; the last depression resulted in the introduction of the triple-expansion engine with high-pressure boilers; in mild steel being substituted for iron as the material for the construction of the hulls of vessels; in many other structural improvements; and, lastly, in an enormous increase in the size of the vessels themselves. It would therefore be interesting to forecast whether the whaleback type of steamer is likely to be one of the improvements resulting from the present depression of the freight market.

I have to apologize for this long apparent digression from the subject of this paper, which I shall now proceed to take in hand.

The ordinary whaleback steamer of the American lakes, of which the *Charles W. Wetmore* is a modern type, I venture to say is not a suitable or efficient craft for commercial purposes on the high seas. The objections—and I presume to think you will agree with me—are the spoon-shaped bow, the want of proper means of communication from end to end of the vessel, thereby diminishing the comfort of the crew, the cramped facilities for navigation, the absence of sail power, and the want of feeding arrangements when carrying bulk cargoes (there being no hatches with coamings running longitudinally along the vessel, the hatches being part of the plating of the structure, which are bolted with screw bolts, and kept tight with packing.) The delay caused by this arrangement is very apparent, leading one almost to the conclusion that the designers and builders were much behind this age of quick despatch; moreover, when carrying bulk cargoes, without the proper means of feeding by trunk hatches, the vessel's safety might be endangered by the shifting of cargo.

If you will permit me, I propose further on to show you, from information and plans I have obtained, how these objections are proposed to be dealt with. I would here remark that I am informed that some of these designs, with the cross sections, have been submitted to the Bureau Veritas for classification, and have been willingly approved of by them; but I learn that

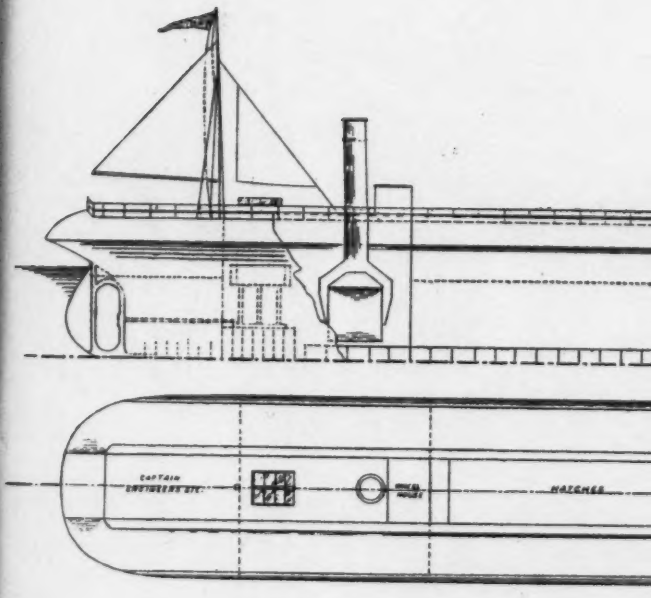
the larger and more important classification authorities, Lloyd's; while approving of the general principles of construction, have been unable to agree to a freeboard satisfactory to the builders and owners. However, the point of interest is, whether many of the direct advantages of this class of vessel should not be embodied in regular sea-going cargo vessels.

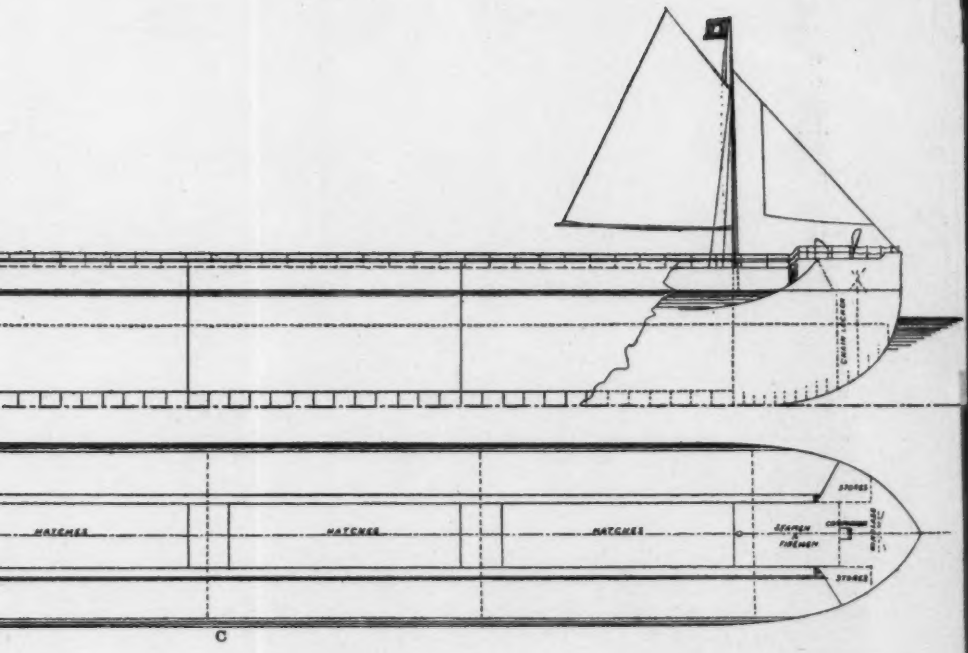
The principal feature which is claimed in connection with whaleback steamers, is the lesser percentage of spare buoyancy with which this class of vessel seems so far to have been successfully navigated on the American lakes, and with which, it may be assumed, they can also be navigated on the high seas. It is superfluous for me to say that the question of spare buoyancy is a complex one, and one which has been largely, and is continually, employing the minds of naval architects. Theoretically speaking, it is well known that a vessel with only 1 per cent. of spare buoyancy would be unsinkable if it were absolutely impossible for the water to get access to her; but so far our ordinary tramp steamers, which are built for the carrying of large deadweight cargoes, have been so constructed as to have, when fully laden, a considerable percentage of spare buoyancy, ranging from 25 per cent. to 35 per cent. A few of the principal reasons for this apparently large amount of spare buoyancy are:

Firstly, that all the necessary openings, such as companions, hatches, &c., may be raised sufficiently high above the level of the sea. This is all the more necessary in the ordinary tramp steamer with bulwarks, because the decks are capable of holding huge quantities of water, which affect both her buoyancy and her stability, so that, unless a considerable freeboard is allowed to vessels of this class, each succeeding wave in heavy weather would threaten to engulf the whole structure. Therefore it is necessary for the comfort of the crew, whose accommodation is generally on a level with the decks, that they should be kept as free of water as possible; still, although with the freeboard now assigned tramp steamers may be perfectly seaworthy, they may in heavy weather, prove anything but comfortable ships, as the water will often gain access to the crews' quarters and other openings.

Secondly, our ships are invariably designed and built to carry a stipulated deadweight cargo on a fixed freeboard. If a ship were loaded down largely in excess of this stipulated cargo, thereby lessening the freeboard and spare buoyancy, there would certainly be an increased possibility of straining and a general unseaworthiness in heavy weather. In this matter of freeboard and spare buoyancy, no one can be surprised that the Board of Trade, meeting with a considerable amount of opposition from the ship-owning classes, should have arranged with Lloyd's Register to take over the permanent responsibility of fixing it.

Thirdly, the comfort and safety of the crew. In an ordinary tramp steamer a considerable amount of the work of the vessel has to be done on deck, the deck being an integral part of the whole ship, and as wide, or nearly as wide, as the vessel herself, being in fact one of the largest surfaces which a ship offers at any part. The whaleback steamer departs from this mode of construction in so far as, instead of having a large deck upon which to work the vessel, only a small gangway is used as a means of communication fore and aft. Therefore, instead of being decked, she is built over with easy curves, with similar scantlings as the hull of the ship, and, while offering no surface to the sea, it is sufficiently strong to withstand the buffeting of the waves; also, there is no spring or sheer, the vessel being dead straight. The vessel is practically built as a tube, while an ordinary steamer is built in the shape of a half-tube, or, to be more accurate, in the shape of a box. You will notice from the midship section that, as far as the plans here shown of whaleback steamers are concerned, they give hatches which are intended to be almost continuous, running from the forward part of the ship to the fore engine-room bulkhead. You will also notice the great facility with which cargoes can be trimmed in such vessels, as bulk cargoes, like grain and coal, will practically settle themselves and fill up the spaces in the course of settling, thus saving considerably in the expense of stowage. These midship sections have, moreover, the advantage of largely increasing the stability of the vessel. If in the existing type of

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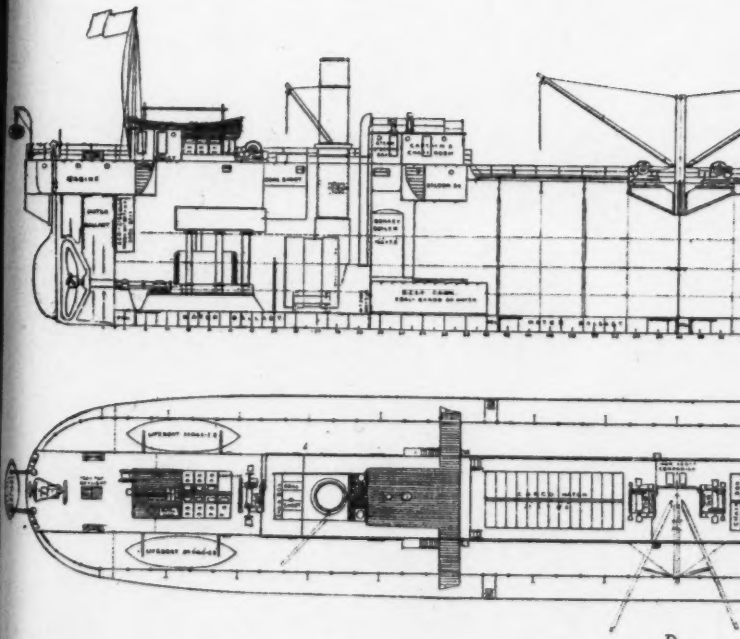

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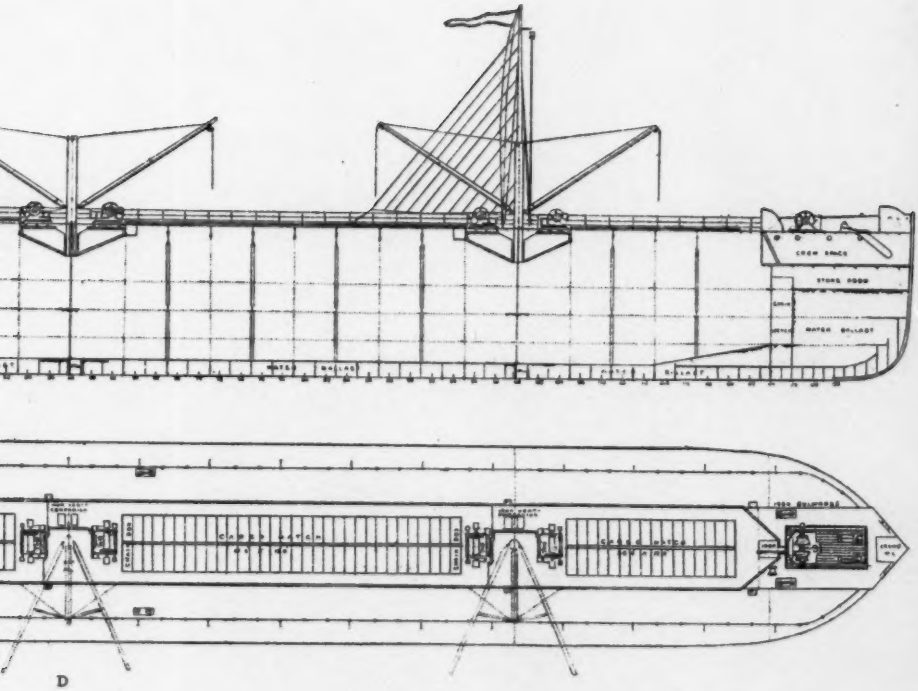




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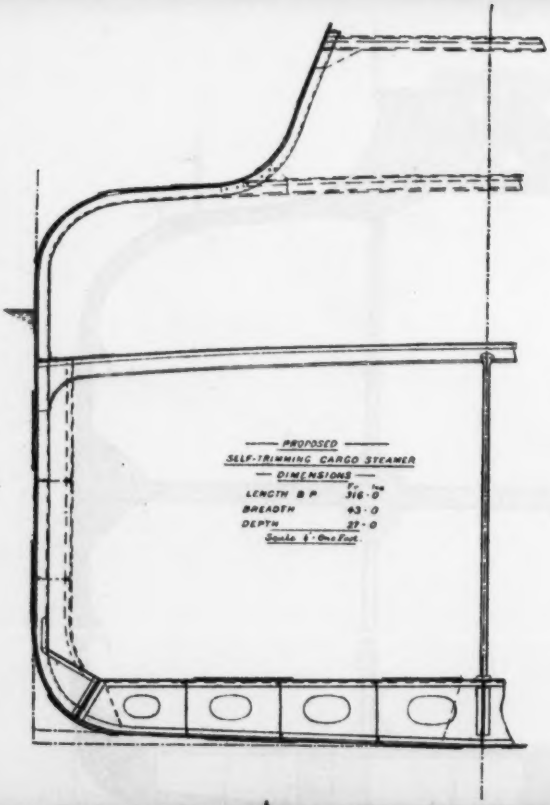
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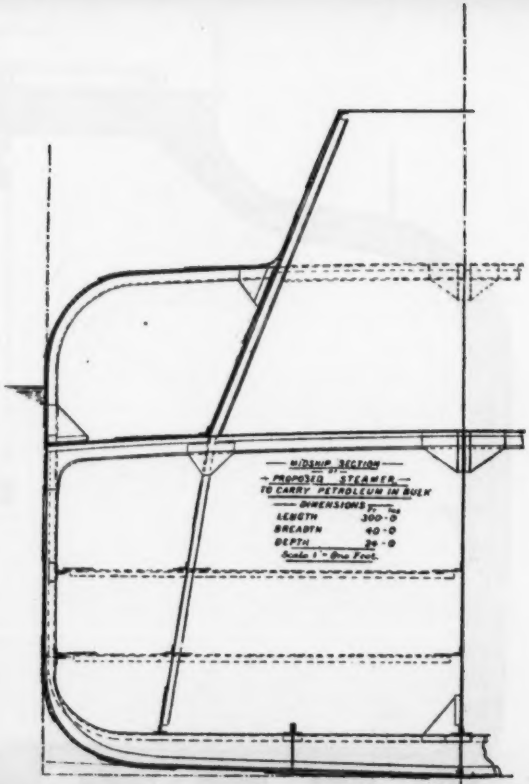
BREADTH 43·0
DEPTH 27·0
Scale 1" = One Foot.


MIDSHIP SECTION
PROPOSED STEAMER
TO CARRY PETROLEUM IN BULK
DIMENSIONS
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BREADTH 40·0
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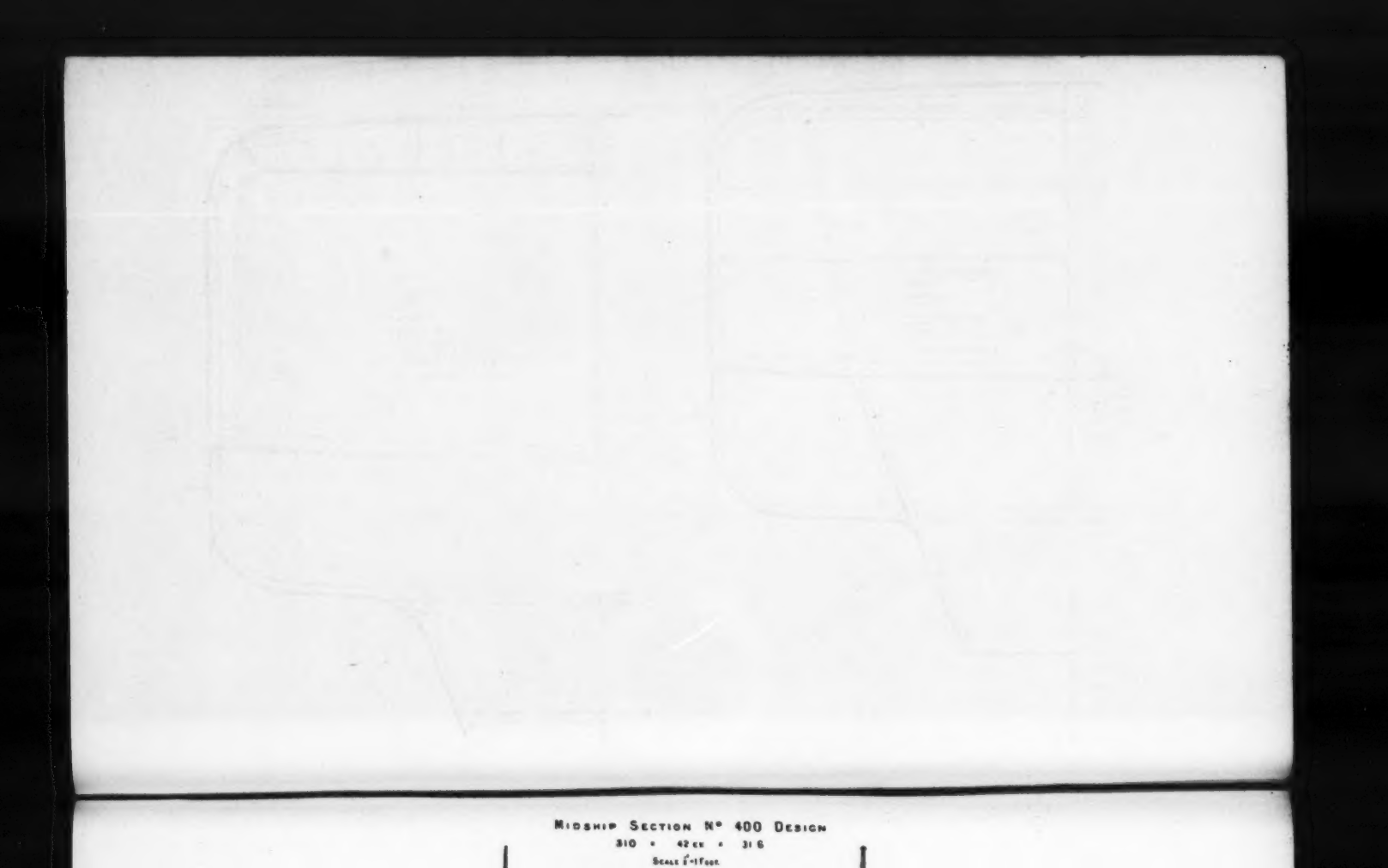
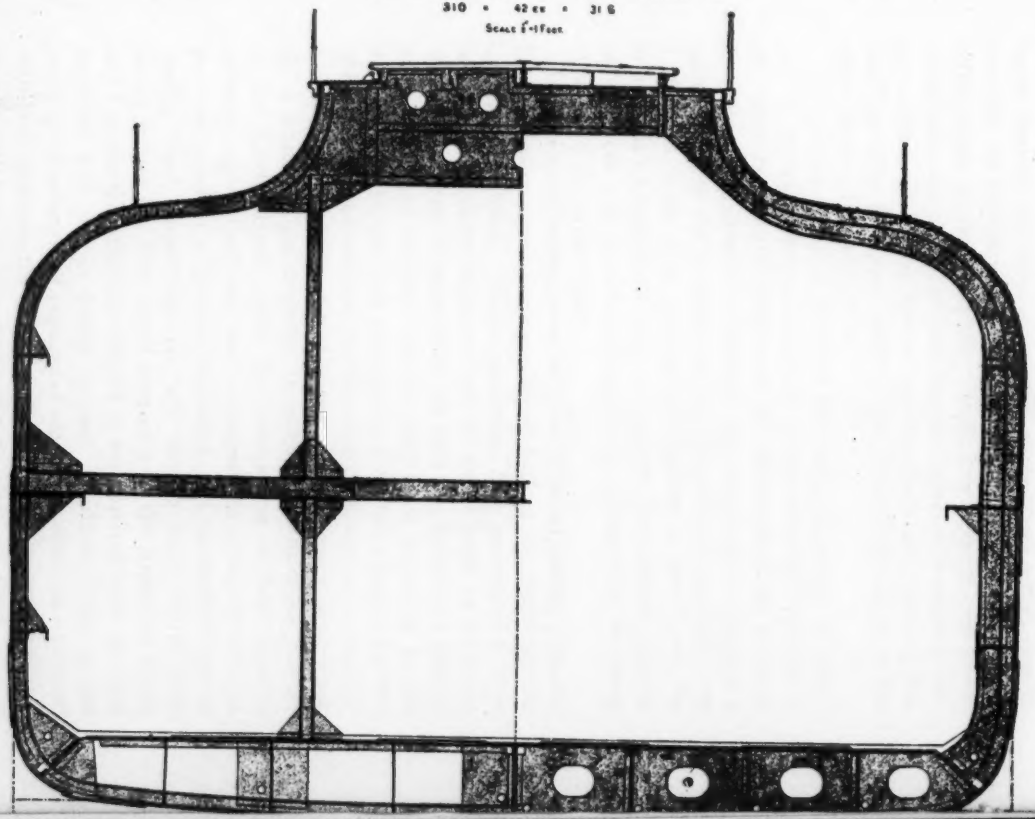
Scale 1" = One Foot.


Midship Section N° 400 Design
310 × 42 ex × 31 6
Scale 1"=1 Foot

MIDSHIP SECTION N° 400 DESIGN

310 × 42 ex × 31 6

SCALE 1"=1 FOOT.



cargo steamer, the cargo is not well stowed, and settles over to one side, the tendency to capsize, after the vessel has reached a certain angle, increases rapidly. Such, it is apparent even to the casual observer, cannot be the case in a vessel with midship sections like those shown, and we may therefore safely assume that this type gives increased stability, and reduces the danger of the cargo shifting to a minimum.

It is not necessary to dwell on the saving in weight of materials in the whaleback construction, as this must be apparent to all. How far the additional strength derived from the shape of these vessels may tend to diminish the scantlings is of course a matter between the builders and the classification societies; but I have no doubt that, in practical experience, it will soon be found that whaleback steamers of a given dead-weight capacity may be built with considerably lighter scantlings than the tramp steamer of the present day.

Further consideration must be given to the advantage in whaleback steamers to the largely reduced surface on which the sea can exert its force. Those gentlemen here present who have been to sea in cargo steamers, will be aware what an improvement a good tumble home from the load line makes in a vessel's behavior in bad weather. In the whaleback, according to the drawing here shown, this principle receives the greatest amount of effect, and I understand that the whaleback steamers generally are very easy at sea, and that water seldom breaks over them. As a matter of practicability, in adapting a whaleback steamer to the North Atlantic trade, the construction of these exposed surfaces, together with any deck arrangements or superstructures, and the question of proper ventilation, will necessitate special study. Such superstructures will require to be built much stronger than has been found necessary on the American lakes, and I doubt if additional strength is not required over the deck erections now in our tramp steamer. Further, owing to the much greater length of voyages of sea-going vessels as compared with lake steamers, the question of ventilation in continued bad weather will have to be a matter of consideration; recent science

has, it appears to me, placed ample means at the disposal of the shipbuilder to satisfactorily solve this problem.

Another feature in a whaleback steamer, which I rather admire, is that the engines are invarible placed aft. The first cargo steamers built, among which I may cite the *John Bowes*, had their engines placed aft, but it was subsequently found that the ordinary jet condensing engines made it impossible to manipulate the coal supply on long voyages without additional expense, or without entirely upsetting the trim of the vessel. The engines were consequently placed amidships, and although since that time the triple-expansion engines have come into general use, and although the consumption of coal per I.H.P. is only 1½ lbs. per horse, as compared with 4 lbs. in the old days, yet we still continue to place the engines amidships, although, with the assistance of water ballast trimming tanks, there now exists no difficulty in keeping such a ship in trim during an ordinary voyage. Now, the advantages of having the engines placed aft are great.

First, there is a much shorter main shaft, therefore less weight of shafting, tunnel plating, and casings to carry; a less number of bearings, consequently less first cost, and less permanent expense for lubricating, &c.

Secondly, by placing the engines amidships the space occupied is far greater than the displacement by the weight of machinery and coals.

Thirdly, by carrying the engines and bunker coals amidships —say in a steamer 300 ft. by 40 ft. with a 40 ft. engine space, and 20 ft. draught of water—the required space for machinery, &c., would displace say 800 tons, while the engines and boilers will weigh probably under 200 tons, and the bunkers, when full, only a further 200 tons. This means that in each of the holds there is carried about 200 tons, when the bunkers are full, and when empty about 300 tons, more than the fore and after holds actually displace, consequently there is a constant hogging strain at each end of the engine space of 200 to 300 tons. Now, it is in this middle part of the ship, occupied by the engines, where a vessel is best suited to carry heavy cargo; and by placing the

engines aft, this center part of the vessel is secured for it, and permanent strain would not exist, or if it did, it would be only in a small degree in comparison. So, as a matter of fact, with careful calculation, a ship with the engines aft might be built with lighter scantlings, and still have the same strength and efficiency; or, in other words, if built with the same scantlings, her strength would be greater.

This, therefore, is another feature which, in my opinion, has been appreciated in America; while we (excepting in small boats) continue, in our characteristically conservative way, to build cargo boats and place the engines amidships.

There is another point I would like you to look into, viz., that by reducing the air surface above water, an advantage is gained in speed. The superstructures on English cargo steamers occupying, as they generally do, the whole width of the ship, offer an enormous surface to air resistance, which, in the case of the American whaleback steamer, is almost *nil*. Moreover, the force of the seas in rough weather, particularly when steaming head to wind, dashing against these superstructures must necessarily very much retard the vessel's progress.

As compared with vessels of the ordinary cargo-carrying type, it appears, therefore, that the principal advantages of a whaleback steamer are:

Firstly, less surplus buoyancy is required; or, in other words, a vessel of a given tonnage will carry more deadweight cargo.

Secondly, owing to the shape above the load-line, together with the circumstance of the engines being placed aft, the whaleback is stronger than the ordinary tramp boat, presuming, of course, that the scantlings are similar.

Thirdly, the reduced amount of superstructures gives a reduced air and wave resistance.

On the other hand, there are apparent drawbacks in the whaleback steamer; and, unless these are modified and intelligently dealt with, their adoption for the carrying trade on the high seas will present many difficulties. Some of these are:

Firstly, in case of injury to the ship's hull, the reduced spare buoyancy would increase in proportion the danger of sinking

Secondly, the absence of masts and sails, in case of a breakdown of the machinery, would be a serious cause of helplessness and danger. I may here state that it would be practically impossible to have masts in a whaleback steamer of the American type, and to work the sails with effect at sea from the narrow platform which serves in place of a deck. Therefore, if built without sails, whaleback steamers should be fitted with twin screws and engines.

Thirdly, the comfort of the crew would be less than in a steamer with a large and comfortable deck, where, in fine and moderate weather, the crew can get about to work, and at any rate, breathe the fresh air. As a consequence, in a whaleback steamer running on the high seas, an improvement in the accommodation and a perfect system of ventilation would have to be arranged for the crew. None of these drawbacks, however, offer any serious difficulties, and have already been dealt with by several members of this Institution.

Looking at the whaleback steamer as a type, I venture to say it possesses many structural and commercial advantages over the ordinary cargo boat as now built in this country. I would like to draw your attention to the fact that the low rates of freights which are paid on the American lakes, taken together with the higher wages of the crew, conclusively prove that the vessels do their work very economically, carrying large cargoes at fair speeds and on a low consumption.

The introduction of a similar type of vessel for the general oversea carrying trade seems therefore merely a matter of time. I would here mention that in the Caspian Sea petroleum tank steamers were employed as long as twelve to fifteen years ago, while their adoption for ocean traffic is of recent date. It is therefore possible that, in a like manner, we may take the whaleback from the American lakes.

Our American cousins possess undoubtedly a good deal of originality and great ingenuity in shipbuilding, which fact is evinced by their splendid river steamers, although I am informed that the invention of the whaleback steamer has to be credited to a Scotchman, Captain McDougall. It has, however,

been readily adopted on the American lakes, showing the enterprising spirit of the Americans, and their appreciation of economical means of transport. As lake steamers for cargo-carrying purposes, they appear to have come very close to perfection, and I venture to confidently look forward to the time when the American lake type of whaleback steamer, improved and made efficient for oversea carrying, will become the great cargo boat of our country.

At the present time there is practically no difference in the type of design of a cargo boat and a passenger steamer. The former, though generally slower, can easily be converted to do the work of the latter. Still the work required from the one so materially differs from the other that we may anticipate, with the whaleback type of steamer, to see their external distinctions more apparent.

It had been my intention, when starting this paper, to have submitted drawings of my own to illustrate to you my ideas of what a whaleback steamer should be for safely navigating the high seas, but, finding others were in the field at the same time, and whose drawings had been made public and their ideas so parallel with my own, I concluded I could not do better than show you the excellent drawings and designs of my friends, Messrs. Oswald and Doxford. I have them to thank, and commend to your thanks, Mr. T. R. Oswald, of Milford, for the two midship cross-sections, marked "*A*" and "*B*," showing a cargo boat and a petroleum tank steamer, also a drawing, marked "*C*," showing longitudinal section and deck plan.

I have likewise to thank and to commend to your thanks, Messrs. Doxford, Limited, for the drawings *D* and *E*.

I might mention that the question of discharging whaleback steamers with continuous hatches has, I understand, been dealt with by Mr. Joseph Temperley, who proposes to run a continuous shaft some 10 feet above the level of the hatches, worked by an auxiliary engine in the engine room. Mr. George B. Hunter, of Wallsend, has also, I am informed, made designs for a similar purpose, and these will no doubt be known to the shipping public at an early date.

# NEW EXAMINATIONS FOR ENGINEER OFFICERS OF THE U. S. NAVY.

U. S. NAVY REGULATION CIRCULAR No. 109.

NAVY DEPARTMENT,
WASHINGTON, D. C., *July 25th, 1892.*

U. S. Navy Regulation Circular No. 53, dated December 26, 1888, will be rescinded January 1, 1893, and from that date the following will be substituted therefor. Meanwhile that portion of subject No. 1 of Circular No. 53, which requires the candidate to make plans and drawings, is abolished from this date, and in lieu thereof the part relative to drawing under subject "Duties on shore at a Navy Yard, etc.," will be used.

Before a Passed Assistant Engineer can be promoted to the grade of Chief Engineer in the Navy, he must have been examined by a board of officers of the Medical Corps and found physically qualified, and have established, to the satisfaction of a board of officers of the Engineer Corps, his mental, moral, and professional qualifications to perform efficiently all the duties, both at sea and on shore, of the grade to which he is to be promoted.

A candidate for promotion to the grade of Chief Engineer must have served at least two years at sea as a Passed Assistant Engineer on board a naval steamer.

The Department will furnish the board with an abstract of the candidate's orders to duty.

Interrogatories will be addressed by the board to Commanding Officers and Senior Engineer Officers under whom the candidate may have served, as to his mental, moral and professional fitness for promotion.

The candidate shall then be examined upon the following subjects, the board selecting from the sample questions, under each subject, the number specified.

The questions must be so drawn as to be capable of concise answers, and, other things being equal, brief answers will receive more credit than long ones.

In determining the candidate's professional fitness for promotion the board will, for its own information, mark his work in accordance with the scale given below; and no candidate will be recommended for promotion should the aggregate of marks fall below 700. These marks will not be entered on the record sent to the Department, but the board will, if the result of the candidate's examination is such as to warrant his promotion, report its recommendation in the form prescribed by Section 1504 of the Revised Statutes.

RELATIVE VALUATION OF SUBJECTS.

| | |
|---|---|
| * Record, | 300 |
| Design of machinery, | 100 |
| Duties on board ship, | 125 |
| Duties on shore, | 150 |
| Practical work, | 125 |
| Strength of materials, &c., | 100 |
| Economics, | 100 |
| | 1,000 |
| Lowest satisfactory, | 700 |

DESIGN OF MARINE MACHINERY.

The candidate shall be required to perform the necessary calculations for determining the amount or size of any one of the following items (the choice to be made by the board):

Necessary horse power to secure a given speed of vessel.

† Dimensions of cylinders for a given horse power.

† Dimensions of condenser and pumps for engines of given dimensions.

† Dimensions of a set of boilers to furnish steam for a given horse power.

† Dimensions of propellers to drive a vessel at a given speed.

* The mark on "record" will be based on the answers to the interrogatory letters.

† These dimensions are for those measurements which determine the power and do not include those necessary for strength.

DUTIES AS CHIEF ENGINEER OF A SHIP IN COMMISSION.

(*Two questions.*)

1. Procedure on joining a ship to ascertain that machinery is in proper condition—that is, what parts should be inspected, and how to secure the needed information in the shortest time.

2. Stationing men of engineer's force for steaming watches and for general and fire quarters; the board to give the number of engines and auxiliaries and of the boilers, with idea of general arrangements as regards subdivision, and the candidate to state the necessary number of men required and their assignment.

3. Care of machinery and precautions to be observed while it is in use and while not in use to insure its readiness for service.

4. Economy in the use of coal, oil, &c. (This will involve such considerations as number of boilers to be used for a given power, rate of combustion of coal, steam pressure and point of cut-off to be used, economical speed of ship, best methods of lubrication.)

5. List of parts subject to wear, and course to pursue to maintain efficiency, together with a statement of cases where deterioration is certain and cannot be compensated.

6. List of machine and hand tools carried on modern war vessels, with statement of new and repair work that can be performed. (Both the list of tools and of work will be in a general way, not going into much detail, the object being to see that candidate knows what work can be done on board and what must be done at shop on shore.)

7. A list of the more important stores and spare parts usually carried on modern war vessels.

8. What inspection and tests would be used in selecting coal, oil, and rubber.

DUTIES ON SHORE, AT A NAVY YARD, OR AS AN INSPECTOR OF MACHINERY BUILDING BY CONTRACT.

(*Two questions.*)

1. General survey of the machinery of a ship returned for refitting at end of a cruise; state what parts would require most careful examination and what work would generally be done to put the machinery in thorough condition.

2. State how estimates of time and cost would be made in the case of repair work. (The board to give a statement of character and amount of repairs required.)

3. Name the tools and appliances generally fitted in a modern plant for the building and repair of marine machinery of large size, giving some idea of the size of the various tools, cranes, &c.

4. State amount of work that should reasonably be expected during a working day of eight hours on any one of the following kinds of work:

Turning plain shafting.

Boring large engine cylinder.

Plain work in hydraulic flanging machine. (Thickness of plate to be given.)

Riveting in hydraulic riveter. (Thickness of plates and diameter of rivets to be given.)

Drilling rivet holes in boiler shells. (Thickness of plates, diameter of holes, and kind of drilling machine, to be given.)

Planing valve seats on large cylinders.

Drilling and tapping holes in condenser tube sheets.

5. Give general idea of method of conducting evaporative test of a steam boiler, stating special precautions necessary to insure accurate results.

6. State preparations that would be made for a full-power trial of machinery of a modern war vessel, including stores and instruments that should be furnished.

7. Give general idea of work to be done in "laying up" machinery of a vessel that is to be put in ordinary.

8. Being assigned to duty as Inspector of Machinery, tell special points to be looked after in inspection of any two of the following:

Cylinders.

Condenser.

Boilers.

Shafting.

Piston and connecting rods and valve stems.

Pistons and valves.

Bed plates.

Propellers.

Boiler and condenser tubes.

Brass castings generally.

In addition to the two questions under this head, the candidate will be furnished with a blue print of some part of the machinery of a naval vessel and required to write such a specification of the same as would be drawn to accompany the contract.

PRACTICAL WORK.

(*One question.*)

1. Molding any large piece of machinery in loam, such as a cylinder, propeller, condenser, &c., from a pattern.

2. Making pattern for a cylinder or other complicated piece of machinery.

3. Making propeller pattern.

4. Molding a propeller by sweeping up.

5. Machine work necessary to put a cylinder casting, as received from foundry, in condition for going in ship.

6. Machine work on a built-up propeller.

7. Machine work on a crank shaft, connecting rod, or piston rod.

8. Manufacture of any large forging of steel or iron.

9. General description of work of building a large boiler.

10. General description of running lines in ship and erecting engines in place.

11. Boring out and fitting stern tubes and shaft struts.

12. Details of building a condenser.

13. Outline of fitting and erecting steam and exhaust piping, with statement of precautions to be observed.

STRENGTH OF MATERIALS, METALLURGY, SHIPBUILDING.

(*Three questions, one on each subject.*)

(The use of works of reference will be permitted in solving problems.)

1. Work out thickness of shell, detail of riveting, thickness of furnaces, diameter of braces in steam space, size and spacing of stays for a cylindrical boiler of given diameter and steam pressure.

2. Design a crank shaft for engines of a given size from data furnished.

3. Design piston rod and connecting rod for given engine.

4. Work out principal dimensions for a cylinder of given engine, including steam ports.

5. Give brief outline of process of making cast iron, explaining how different qualities are produced.

6. Give brief outline of common method of making wrought-iron bars or plates.

7. Describe briefly the principal methods of making steel used in machinery and structural work.

8. Explain in a general way the manufacture of various kinds of brasses or bronzes, explaining how the proportions of ingredients affect the principal qualities, such as strength, hardness, brittleness, &c.

9. Explain in a general way the manufacture of the so-called "white metals" or "anti-friction" metals, the way in which they are used, and the reasons for their use.

10. Explain the methods of framing used in war vessels constructed of steel, particularly in the space to be occupied by machinery.

11. Explain water-tight subdivision on war vessels.

12. Explain the framing and working of plates at the stern post and where the shaft tubes are attached.

13. Explain the drainage system and its connection to the engine-room pumps.

14. Explain the precautions to be taken in attaching valves to hull to maintain the strength and prevent corrosion.

15. Explain the fitting of decks and framing of hatches near the machinery compartments.

16. Explain briefly center of gravity, center of buoyancy and metacenter. Discuss briefly the considerations that affect stability and stiffness.

ECONOMICS OF MACHINERY.

(*One question.*)

1. Explain briefly the advantages and disadvantages of high

steam-pressures and multiple-expansion engines, both for marine machinery in general and for war vessels.

2. Discuss briefly the advantages and disadvantages of the various styles of valve gear and valves in general use, and of those which are used in special cases where saving of weight and space is important.

3. Discuss briefly the considerations that govern the choice of a particular style of boiler, noting the relative merits of shell and coil boilers.

4. Discuss the methods of propulsion, giving important features to be secured in an efficient propeller, and explaining why the form of propeller now in use is most desirable; or, if you think so, why any other form would be preferable.

5. Discuss the question of the methods of securing great power in marine machinery on light weight, showing what is necessary, how far it is safe to go, and precautions in inspection of material and perfection of workmanship to be observed.

B. F. TRACY,
*Secretary of the Navy.*

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U. S. NAVY REGULATION CIRCULAR NO. 110.

NAVY DEPARTMENT,
WASHINGTON, D. C., *July 25, 1892.*

U. S. Navy Regulation Circular No. 52, dated December 26, 1888, will be rescinded January 1, 1893, and from that date the following will be substituted therefor. Meanwhile subject No. 7 of Circular No. 52 is abolished from this date, and in lieu thereof, the subject "Drawing," as given below, will be used.

Before an Assistant Engineer can be promoted to the grade of Passed Assistant Engineer in the Navy, he must have been examined by a board of officers of the Medical Corps and found physically qualified, and have established, to the satisfaction of a board of officers of the Engineer Corps, his mental, moral and professional qualifications to perform efficiently all the duties, both at sea and on shore, of the grade to which he is to be promoted.

A candidate for promotion to the grade of Passed Assistant Engineer must have served at least three years at sea as an Assistant Engineer on board a naval steamer.

The Department will furnish the board with an abstract of the candidate's orders to duty.

Interrogatories will be addressed by the board to Commanding Officers and Senior Engineer Officers, under whom the candidate may have served, as to his mental, moral and professional fitness for promotion.

The candidate shall then be examined upon the following subjects, the board selecting from the sample questions, under each subject, the number specified.

The questions must be so drawn as to be capable of concise answers, and, other things being equal, brief answers will receive more credit than long ones.

In determining the candidate's professional fitness for promotion the board will, for its own information, mark his work in accordance with the scale given below; and no candidate will be recommended for promotion should the aggregate of marks fall below 700. These marks will not be entered on the record sent to the Department, but the board will, if the result of the candidate's examination is such as to warrant his promotion, report its recommendation in the form prescribed by section 1504 of the Revised Statutes.

RELATIVE VALUATION OF SUBJECTS.

| | |
|---|---|
| * Record, | 75 |
| Boilers, | 80 |
| Engines, | 70 |
| Valves, | 90 |
| Condensers and pumps, | 80 |
| Auxiliary machinery, | 75 |
| Practical building and repairing, | 120 |
| Propellers, theory of steam engine, | 115 |
| Strength of materials, | 100 |
| Metallurgy, | 60 |
| Electricity, | 60 |

* The mark on "Record" will be based on the answers to the interrogatory letters.

| | |
|---|---|
| Drawing, | 30 |
| Modern languages, | 45 |
| | 1,000 |
| Lowest satisfactory, | 700 |

BOILERS.

(*Two questions.*)

1. Give brief description of a boiler, explaining the functions of the different parts.

2. Name the different classes of shell boilers commonly used in modern war vessels and describe one (to be selected by board).

3. Name the different tubulous or coil boilers that are generally considered best and describe one (to be selected by board).

4. Give the relative advantages and disadvantages of shell boilers and coil or tubulous boilers.

5. Give brief explanation of different methods of forced draft and state its advantages and disadvantages; what, if any, bad effects it has on boiler; air pressure carried with different classes of boilers; amount of coal burned per square foot of grate surface with different air pressures.

6. Name attachments to boilers and describe any three (to be selected by board).

7. Name the principal causes of the deterioration of boilers and the means of prevention.

8. Name methods of increasing circulation in boilers and describe one with which candidate is familiar.

ENGINES.

(*Two questions.*)

1. Describe briefly the engines used in modern war vessels, as regards their position and arrangement of cylinders, explaining the conditions that lead to the selection of one type rather than another.

2. Describe briefly the types of engines used in modern war vessels from the standpoint of the way in which the steam is expanded, and note any changes in arrangement of valves, receivers, &c., consequent on increase of the number of stages in the expansion.

3. Name the attachments to the engines of modern war vessels and describe three (to be selected by board).

4. Explain the means employed to secure powerful engines of comparatively light weight.

VALVES AND VALVE GEARS.

(*Two questions.*)

1. Name the valves used with the engines of modern war vessels, and describe the piston valve and one other. Explain the advantages and disadvantages of the two valves described.

2. Name the materials of which valves are made, and the liners and false faces to valve seats, explaining reasons for the choice of materials.

3. Name the different kinds of valve gears commonly used with the engines of modern war vessels, and describe the Stephenson link and one of the radial valve gears.

4. State briefly the advantages claimed for the radial valve gears most frequently used, and state your opinion, with reasons, for the truth or falsity of their claims.

5. Explain the provision made for varying the degree of expansion employed with modern engines using modern valve gears, and what, if any difficulty, from a practical point of view, there is in using high rates of expansion; also what provision is made to enable the engines to be backed at full power while using a considerable degree of expansion.

6. State any devices with which you are acquainted for reducing wear on the valve gear and for doing the actual work of moving the valves, leaving the eccentric or equivalent device only the work of determining the phases of the valve movement. Describe one of these.

CONDENSERS AND PUMPS.

(*Two questions.*)

1. Describe the principal features of the condensers used on modern war vessels, including the material of which made, method of packing the tubes, provision for proper distribution of the steam, &c.

2. Name the attachments to a modern condenser, including the various pipe nozzles.

3. Describe briefly the air and circulating pumps commonly used with the engines of modern war vessels, and give the advantages due to use of independent pumps; also the advantages and disadvantages of combined air and circulating pumps.

4. Describe the type of boiler feed pump most often used, and tell why this type is preferred.

5. Name the steam pumps most often used as auxiliaries on board ship, and describe one of them.

6. Explain how the pistons and rods of air, circulating, feed and auxiliary pumps are packed, both for low and high pressures, and for hot and cold water. Tell the material of which the valves of the water cylinders are made for different pressures and temperatures.

7. Name any derangements to which the pumps in previous question are liable, it being assumed that they are in good order.

AUXILIARY MACHINERY.

(*Two questions.*)

1. Name the different types of reversing engines commonly used with modern machinery, and describe one.

2. Describe the evaporators and distillers in common use on war vessels and name the attachments. Give approximate output of an evaporator of given size, when used for making drinking water and when used for supplying deficiency of feed.

3. Describe any good ash hoist in common use with which you are familiar.

4. Describe briefly the steam capstans and windlasses now fitted to war vessels.

5. Describe briefly any good steam or hydraulic steering gear with which you are familiar.

6. Describe any good engine-room telegraph fitted for repeating the signal.

7. Name the different methods of fitting turret-turning machinery, and describe one with which you are familiar.

8. Explain the accumulator and regulator used with hydraulic machinery.

9. Name the different types of refrigerating machines used on board ship and describe any one with which you are familiar.

10. Describe any efficient governor used with marine engines.

PRACTICAL BUILDING AND REPAIRING MACHINERY.

(*Two questions.*)

1. Describe briefly the steps in building a marine boiler, including such items as preparing the plates, laying out and trimming to size, flanging, annealing, fitting furnaces and tubes, &c.

2. Describe briefly the machine work on a large cylinder of a marine engine after it is delivered from the foundry to fit it for erection.

3. Describe briefly the machine work on any one of the following pieces: connecting rod with forked end; piston rod and cross head; solid crank shaft; built-up crank shaft; propeller shaft and propeller, either solid or with adjustable blades.

4. Describe briefly the operation of boring out shaft tubes and struts.

5. Give a brief explanation of the salient features of moulding, including the kinds of sand used, venting, cores, securing moulds, &c.

6. Describe briefly the process of moulding a large cylinder, either from a pattern or by "sweeping up" and in dry sand or loam. (Candidate to choose which method and material in which moulded.)

7. Describe briefly the moulding of a composition propeller by "sweeping up" or from pattern and in dry sand or loam. (Candidate to choose.)

8. Describe process of repairing castings by "burning" and explain limitations and precautions to be observed.

9. Explain the process of melting cast iron in a cupola, including a brief description of a modern cupola.

10 Explain the process of melting composition or brass for large and small castings.

11. Explain operation of making copper pipe and note the precautions to be observed to secure good work.

12. Describe process of making a large wrought-iron forging; also a large steel forging.

13. Describe method of repairing broken parts of machinery on board ship. (The board to select two cases and state the circumstances.)

14. Describe process of fitting white metal in a bearing and of repairing it if melted out by hot journal.

15. Describe process of fitting lignum vitæ bearings, giving precautions to be observed.

16. Explain briefly the salient features of pattern making in connection with marine machinery.

PROPELLERS, THEORY OF STEAM ENGINE.

(*Two questions.*)

1. Give the generally accepted theory of propelling instruments and its application to the screw propeller.

2. Describe the essential features of a good screw propeller and explain how far they are carried out in practice.

3. Describe briefly the types of screws commonly fitted to modern war vessels.

4. Explain the advantages and disadvantages of twin and triple screws.

5. Explain the advantages of high speed in marine engines and tell how it is secured.

6. Explain the influence of inertia of reciprocating parts of engines on steadiness of running, and also influence of number and position of cranks on uniformity of crank effort. Explain method of laying out a curve of crank effort.

7. Explain the effect of multiple cylinder engines on economy in use of steam and give approximate figures for steam and coal per I.H.P. in different types of engines.

8. Give the first and the second laws of thermodynamics. Give Carnot's function and explain its use and bearing on the performance of engines in practice. Explain the advantages and disadvantages of using steam of high pressure.

9. Explain the limitations to useful expansion. Show how to compute amount of water used from an indicator diagram and

explain why the amount thus calculated is not the same as that found by actual measurement of feed.

10. Explain what is meant by superheated steam and the advantages and disadvantages of its use.

11. Explain briefly why steam is a better vehicle for heat engines than other vapors with less latent heat and lower boiling point.

12. Explain briefly the essential features of a correct reducing motion for steam-engine indicators and sketch one form.

13. Explain briefly the construction of the steam-engine indicator; demonstrate the degree of accuracy of the pencil movement of any one, and explain what difference in the selection of the piston and drum springs is caused by difference in speed of engine.

14. Explain the standardization of indicators and the necessity for it.

15. Explain the correction of indicator cards by the result obtained from standardization of the indicators and tell how it is done practically for a large number of cards, as in the case of a trial trip.

16. Draw a good practical card, as obtained from an engine in good condition, and show by dotted lines the result of defect in adjustment or fitting of the valve and other parts.

17. Explain briefly the composition of coal. Show how to calculate the thermal value of coal from its percentage composition. Explain briefly chimney draft and the effect of proportions of chimney. Tell the bearing of forced draft on the economy of combustion. Calculate temperature of furnace from data given by board and tell how it is determined practically.

18. Discuss briefly the economic and practical advantages and disadvantages of using liquid fuel instead of coal on war vessels.

STRENGTH OF MATERIALS.

(*Two questions.*)

NOTE.—In working problems under this subject free use of text books and works of reference will be permitted.

1. Definition of principal terms employed, such as stress,

strain, elastic limit, permanent set, fatigue, neutral axis, ultimate strength, safe working strength, factor of safety, modulus of elasticity, &c.

2. Explain the effect of prolonged application of stress and of repetition of stress through wide range; also of alternation of stresses of opposite kinds on safe working strength of a material.

3. Explain how the ultimate strength and elastic limit are determined in practice and explain what is meant by the expression "strength per square inch." Give brief description of the essential features of any good testing machine with which you are familiar.

4. Describe the effect of variations of temperature on the tensile strength of the more important metals used in marine machinery.

5. Determine the thickness of shell, thickness of furnace, and diameter of braces to heads for a boiler from data furnished by the board. Show how to determine the strength of a riveted joint, as compared with the solid sheet, and state what practical considerations modify the theoretical percentage found, as you have described.

6. Determine the proper dimensions of the piston rod and connecting rod, or the crank shaft, of an engine from data furnished by board.

7. Show how to determine which is the stronger column, a square or round one of same cross-sectional area; also, with same cross-sectional area a solid or hollow one.

8. Work a problem in strength of beams from data by board. What is the strongest shape of beam in steel or wrought iron in general use? Explain what governs the choice of I, T, angle, bulb, or Z bars for use as beams.

9. Explain how you would determine the proper size for the key or feather for securing a composition propeller on a steel shaft. Explain the limiting resistance to crushing in metals which "flow" under great stress, and state the metals or class of metals which present this quality.

10. Explain briefly the effect of the shape of test piece on

ultimate tensile strength and elongation and tell the general practice in respect of shape and size of test piece.

11. Give the tests, other than by machine, for the steel parts of marine machinery.

12. Explain the difference between the resistance to direct crushing and the resistance to compression and give some idea of how you would determine when one and when the other would apply.

13. Name the parts of marine machinery now commonly made of forged or rolled steel; also those commonly made of steel castings.

14. Give an approximate figure for the ultimate tensile strength of the following materials, of good quality, such as would be passed for use in marine machinery: Steel boiler plate; wrought-iron boiler-plate; steel forgings; steel castings; bar iron (small sizes); wrought-iron forgings like engine shafts; ordinary Navy composition; Muntz metal; naval brass; manganese bronze; phosphor bronze; copper.

METALLURGY.

(*Two questions.*)

1. Name the principal iron ores and describe briefly the operation of making pig iron in the blast furnace.

2. Describe the common methods of making wrought iron.

3. Explain the distinction between cast and wrought iron and steel, and state what kinds of the latter are adapted to use as parts of marine machinery.

4. Give a general description of the principal methods of making structural steel and give details of the open-hearth process.

5. Explain briefly the difference between the "acid" and the "basic" methods of making steel and explain the importance of the latter. Explain the effect of the principal metalloids found in steel and state the maximum amount of each permitted in steel boiler plate.

6. Explain briefly the different methods of making ingot copper and state what impurities are likely to be found in the ingots and their effect.

7. Explain briefly the difference between brass and bronze and explain the effect of varying the proportions of the constituents both as regards strength and other characteristics.

8. Give a brief description of the so-called "strong bronzes," explaining their composition and the theory as to the effect of the special ingredients which give the distinctive names.

9. Give a brief account of the defects found in steel castings and the explanations usually given to account for them.

ELECTRICITY.

(*Two questions.*)

1. Describe the essential features of a dynamo electric machine and give a brief account of any standard machine in common use.

2. Explain briefly the construction of electric motors and wherein they differ from dynamos.

3. Define the electric terms in common use in connection with dynamos and motors.

4. Explain the principles of electric lighting by incandescent lamps and tell what means are employed in practice to secure a steady light, whatever number of lamps may be in use.

5. Explain the advantages of transmission of power by electricity and state under what circumstances it would be more economical than the direct application of steam power.

6. Give data of relative weight of plant to do a given amount of work (say 100 I.H.P. at point of application) on board ship when steam power is applied direct and when electric motors are to be used, it being assumed that steam is taken in each case from the auxiliary steam pipe.

7. Give a brief description of the storage battery, as now constructed, and state the advantages and disadvantages, in your judgment, of their use in connection with naval vessels or their dependencies.

8. Give precautions to be observed in the practical use of dynamos and motors and state what mishaps are common or likely to occur.

DRAWING.

The candidate will be furnished a blue print of some portion of the machinery of a naval vessel and will be required to write a description of it, telling the different materials employed and explaining the object of any special features.

MODERN LANGUAGES.

The candidate may choose either French, German, Italian or Spanish as the language in which he wishes to be examined.

He will be required—

1. To translate a short selection from any good author or newspaper, and not of a technical nature.

2. To translate a short selection from some book or journal treating of marine machinery.

The translation will be free, but must preserve the meaning of the original.

B. F. TRACY,
*Secretary of the Navy.*

# NOTES.

## CONTRACTS WITH PRIVATE BUILDERS FOR MACHINERY FOR FRENCH NAVAL VESSELS.

The contracts with private firms who supply machinery for French naval vessels contain some very interesting features, particularly the rigid requirements in regard to the horse power and economy trials. Following are some extracts from the contract for triple-expansion engines and Belleville boilers for a large cruiser:

Within sixty days after the signing of the contract, the contractors must furnish complete plans on tracing cloth of the machinery and boilers. After these have been approved, they must furnish within ten days two sets of blue prints, and within forty days five sets of tracings on tracing cloth. In case of delay, a fine of ten francs per day is imposed.

In the inspection of steel castings, small blow holes will not cause their rejection, provided they do not affect the strength, or, in such articles as pistons, the tightness.

If the boiler rivets are machine driven, they may be made of mild steel, but if they are hand driven, steel rivets will not be allowed, but they must be made of the best wrought iron.

The weight of the machinery complete, as specified in the contract, including the pumps for the main condenser, the feed pumps, bilge pumps, engine-room ventilators, piping, evaporators, feed tanks, sea, suction and discharge cocks, chimneys, exhaust pipes, platforms and all accessories, spare parts, tools, water in boilers, condensers, tanks and piping must not exceed 850 tons.

If the weight of the completed machinery exceeds this limit the contractors will be subject to a penalty of 1,000 francs per ton for the first 15 tons in excess, 2,000 francs per ton for the

second 15 tons, 3,000 francs per ton for the third 15 tons; and, if the total weight exceeds that allowed in the contract by more than 45 tons, the machinery may be rejected.

TRIALS.

After the contractors are satisfied that the machinery is in readiness, it will be inspected and tested in their presence by a commission.

This commission will make all the tests that it deems necessary, with all or a part of the fires lighted, to determine that the boilers are well made, that the feed is abundant, and that the various parts of the engine work with the ordinary means of lubrication from oil and water, regularly and without heating of sufficient intensity to demand a continuous use of sea water even at the maximum speed.

The commission will ascertain that each of the main engines can be driven by the steam from any one of the boilers; that the stoppage of the air and circulating pumps of one of the main engines will not prevent the working of both of the main engines at a slow speed, and that the brakes are sufficient to hold the screws while the engines are being coupled and uncoupled.

It will also ascertain that each of the circulating pumps can, in less than 60 seconds after the order is given, take water directly from the bilge and discharge it into the sea in the quantity specified in the contract; that this manœuvre shall be made without any possible hesitation by one man only from the upper platform of the engines, and without there being any chance for connection between the sea and the bilge.

The commission will also ascertain that the tools and spare parts delivered conform in size, quality and quantity to the provisions of the contract, and that similar pieces are interchangeable. It will ascertain by repeated trial that by means of the hand-reversing gear the engines can be started ahead in less than 45 seconds, and that, upon the order to reverse, the engines can be backed in less than 90 seconds, although they might have been going at full speed ahead. The same must be true in going ahead from backing. With the steam-starting gear these manœu-

vres must be capable of execution without hesitation by a single man in one-third of the time specified for the hand gear, that is, in 15 or 30 seconds.

The commission will also ascertain that with the valves sufficiently closed and with the normal vacuum in the condensers, the engines are able to maintain a normal speed of less than 30 revolutions per minute.

After these examinations, the following trials will be conducted, for each of which the vessels shall be, as nearly as possible, at the designed loadwater line:

*1st. Trial for coal consumption and good working at 8,000 I.H.P., under natural draft, with 24 boilers; duration, 12 hours.*—For this test the engine will work triple-expansion, and all the boilers will be in use. The pressure at the boilers is not to exceed 17 kilos (242 lbs. per square inch), and that at the reducing valve 12 kilos (171 lbs. per square inch). The firing will be done with natural draft. The point of cut-off, which must be maintained at the same point during the whole of the trial, is to be regulated by the contractors so as to develop 8,000 I.H.P. The speed of the main engines not to exceed 125 revolutions per minute.

In case it should be necessary to change the screws, in order to obtain 8,000 horse power without exceeding the 125 revolutions, this change is to be made at the expense and risk of the contractors.

The consumption of coal measured for six hours at the beginning of the trial must not exceed one kilo (2.2046 lbs.) per horse power per hour. If it exceeds $1\frac{1}{10}$ kilo (2.425 lbs.), the machinery may be rejected. If the consumption is less than one kilo., there will be a premium of 400 francs for each gramme (0.0022 lb.) below one kilo.

*2d. Trial of power under forced draft with 21 boilers for four hours.*—The engines will be worked triple expansion, and 21 boilers will be in use. The pressure in the boilers is not to exceed 17 kilos (242 lbs. per sq. in.), and that at the reducing valve 12 kilos (171 lbs. per sq. in.). The combustion will be by

forced draft obtained by jets of steam in the chimneys. The cut-off in the cylinders must remain constant during the whole trial, and will be regulatod by the contractors so as to develop 8,000 I.H.P. If, during this trial, which shall last during four consecutive hours, the total power of 8,000 I.H.P. is not obtained, there will be a penalty of 100 francs for each horse power lacking.

*3d. Trial at maximum power lasting four hours.*—For this trial the engines will work triple expansion, and all the boilers will be in use. The pressure in the boilers is not to exceed 17 kilos (242 lbs. per sq. in.), and at the reducing valves 12 kilos (171 lbs. per sq. in.). The stop valves shall be opened wide, and the cut-off will be at the latest point. Forced draft will be used, and the firing will be pushed as much as possible, so that the engines may develop all the power possible, without, however, the combustion exceeding 170 kilos per sq. met. (34.8 lbs. per sq. ft.) of grate surface.

During this trial, which is to last four consecutive hours, the working of the machinery is to be entirely satisfactory in every respect.

*4th. Trial of good working and of coal consumption at 5,000 horse power; duration 24 hours.*—During this trial all the machinery will be in operation, and as triple expansion. The fires will be under natural draft.

Only 18 boilers will be used. The pressure in the boilers and the point of cut-off at the engines will be regulated by the contractors, so as to develop a collective horse power of 5,000. The cut-off must remain constant during the whole of the trial. The coal consumption during the entire trial must not exceed 850 grammes (1.874 lbs.) per I.H.P per hour.

If the consumption exceeds 850 grammes, there will be a penalty of 800 francs for each gramme in excess. If it exceeds 950 grammes (2.094 lbs.), the machinery may be rejected.

If it be less than 850 grammes, the contractors are to receive a premium of 800 francs for each gramme below 850.

This trial of 24 hours shall include a period of 6 consecutive

hours, taken either at the beginning or at any particular time during the trial selected by the contractors, during which there was no cleaning of the fires, and for these 6 hours the consumption of coal per horse power must not exceed 800 grammes (1.764 lbs.). If the consumption during these 6 hours is in excess of 800 grammes, the contractors will be under a penalty of 400 francs for each gramme in excess.

If it is less than 800 grammes, there will be a premium of 400 francs for each gramme below. The premiums and penalties for these two trials of 24 and of 6 hours will be added.

*5th. Consumption trial at 2,000 horse power lasting 6 hours.*—For this trial all the machinery will be in operation, and at triple expansion. The number of boilers to be used and the pressure to be maintained will be determined by the contractors and notified to the commission at the beginning of the trial. The fires will be worked under natural draft. The cut-off will be determined by the contractors, but must remain constant during the whole trial. The coal consumption during this 6 hour trial must not exceed 850 grammes (1.874 lbs.) per I.H.P. per hour. If it exceeds 850 grammes, the contractors will be under a penalty of 1,600 francs for each gramme in excess. If it exceeds 950 grammes, the machinery may be rejected.

If it is less than 850 grammes there will be a premium of 1,600 francs for each gramme below.

*6th. Various supplementary trials.*—Besides the trials above specified, the commission may make any supplementary trials they may deem desirable, with either forced or natural draft, and with the engines working together or separately, in order to determine the results which it is possible to obtain in the various cases, all of which trials shall be made without any additional compensation to the contractors.

During these trials the contractors will be responsible for the good working of the machinery, but whatever the results obtained, there shall be no penalty.

*7th. Conditions applicable to all the trials.*—In the different trials, the throttle valves will be wide open. The cut-off will be

regulated to the degree necessary to obtain the desired power, and the boiler stop valves will not be partially closed unless this is found to be absolutely necessary to prevent foaming.

The mean revolutions during the trials will be deduced from the observations made at the counter and clock of each engine at the beginning and end of each trial, taking account, if necessary, of the errors in the clocks used.

During the trials the vessel must, as nearly as possible, be steered in a straight line, and the helm will be used as little as possible. When it is necessary to change the course, it will be done to a curve of a large radius.

In each of the trials for power and coal consumption, indicator cards will be taken every twenty minutes, from each of the cylinders of the main engines, and air and circulating pumps, and at the same moment the number of revolutions of each engine will be noted.

The commission will not be required to take indicator cards from the other auxiliaries; it will determine previously the horse power of each of these engines for various speeds on the trial, and will take as the horse power developed the figure corresponding to the mean revolutions, as obtained from the counter attached to each engine during this trial.

To determine the total horse power developed during the trial, it will be calculated from the various observations obtained based on the mean revolutions, throwing out such observations as are manifestly erroneous. In making this determination, the power will be assumed to vary according to the following exponent of the revolutions: For the main engines and the blowers, as the cubes of the revolutions; for the other auxiliaries directly as the revolutions.

The horse power required by the contract will consist of the sum of the powers developed by the cylinders of the following machines: the two main engines, the two engines for the air and circulating pumps, the eight feed pumps in the fire rooms, and the two engine room ventilators.

No account will be taken of the power developed by the steam jet in the chimney during the forced-draft trials.

In the trials for coal consumption the total amount of coal burned will be measured with the utmost care. In determining the premiums and penalties for excess or deficiency of power or coal consumption, no account will be taken of fractions of a horse power or of a gramme of coal.

In all trials and until the vessel is received by the Government, the contractors are responsible for the machinery, and are to execute all the manœuvres and trials demanded by the commission and the officers on board.

During the trials the steam for the starting engine, bilge pumps, ash hoists, dynamos and other auxiliary engines, whose employment will be only what is absolutely necessary, will be furnished from the main boilers.

Account will be taken in the calculations for coal consumption of the amount of coal required for these small engines, but the horse power developed by these engines will not be taken into account in calculating the contract horse power of the motive machinery.

During the trials engineers and firemen from the Navy will have charge of the machinery, although the contractors shall have the right at any time to replace them with their own men. In case the contractors' men are employed, they will be furnished with food and lodging by the Government, but with no pay. The contractors' representatives will be entitled to lodging and a place in the officers' mess when they take part in the trials at sea.

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EXPERIMENTS TO DETERMINE VARIATION IN EFFICIENCY DUE TO JACKETING THE DIFFERENT CYLINDERS OF A TRIPLE-EXPANSION ENGINE.

Mr. Bryan Donkin, Jr., writes to "Engineering," under date of June 4, 1892, as follows:

Having lately been requested to make some feed-water and coal tests on a modern vertical triple marine-type condensing engine, working at 120 lbs. to 145 lbs. steam pressure, I was kindly allowed by the engineers to carry out a series of experiments on the economic effect of the three steam jackets separately and collectively. These will shortly be published in

detail, but your readers might now like to have the broad results.

Experiments were made, not only with boiler steam in all the jackets, but with different and decreasing pressures in the three jackets. The number of jackets used was varied, any one or any two being in action, or none at all.

The results are instructive, and show an advantage of about 12 per cent. in favor of using the three barrel jackets as compared with none. This is at about 55 revolutions per minute, indicating some 175 horses, with a pressure of 116 lbs. in each of the three jackets and about ten expansions.

It is often a debatable point with engineers to which cylinder the jacket should be applied, if only one is used.

The experiments determine this point and form a check upon each other. The low-pressure cylinder jacket gives a much more advantageous result than either of the others, or nearly double the economic gain of both together, and with different pressures of steam on the jackets.

| | Per cent. |
|---|---|
| The H.P. jacket alone gave . . . | 1¼ |
| The I.P. " " " . . . | 2¼ |
| The L.P. " " " . . . | 6½ |

gain of feed water or steam, as compared with the consumption without steam in any of the jackets. The engine was going at about 57 revolutions per minute.

It is interesting to compare the dryness fraction of the steam at the end of each cylinder in the different experiments.

With the three jackets working and 116 lbs. pressure of steam in each, the dryness fraction was—in the high, intermediate and low cylinders respectively, 85½, 86½ and 96 per cent. In other words, the steam, as might be expected, became regularly drier as it passed through the cylinders.

Exactly the reverse takes place without steam in any of the jackets. The dryness fraction being 87, 76 and 64½ per cent. in the three cylinders respectively. More and more water was formed during the journey of the steam through the cylinders, passages and valves. When leaving the low-pressure cylinder,

the proportion was about two-thirds steam and one-third water.

With all the jackets in operation, the steam was nearly dry, as seen above, on leaving the low-pressure cylinder for the condenser. This is important, as little or no heat can be carried from the low-pressure cylinder walls to the condenser without water to convey it.

The most economical result with boiler steam in all the jackets was 14.1 lbs. of steam per indicated horse power per hour (including jacket water), with 146 lbs. pressure and 61 revolutions. The dryness fraction at release in low-pressure cylinder was 97 per cent.

Another result of these tests is that, when boiler pressure was used in all three jackets, more economy was obtained than with boiler steam in high, 75 lbs. in intermediate, and 10 lbs. in low-pressure jacket, and the dryness fraction was also raised.

A pressure gauge was placed on each jacket and an air cock to test for air in the jackets.

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### IRON VERSUS STEEL BOILER TUBES.

In a recent article on the failure of Navy boilers, we made reference to certain experiments which had been carried out in order to test the relative efficiencies of iron and steel as materials for the construction of boiler tubes. By the courtesy of Mr. A. Blechynden of Barrow, we are now able to put before our readers some of the particulars of investigations undertaken by that gentleman. Mr. Blechynden prefers iron tubes to those of steel, but how far he would go in attributing the leaky tube defect to the use of steel tubes we are not aware. It appears, however, that the results of his experiments would warrant him in going a considerable distance in this direction. The first test consisted of heating and cooling two tubes, one of wrought iron and the other of steel. Both tubes were $2\frac{3}{4}$ in. in diameter and .16 in. thickness of metal. At a temperature of 46 deg. Fahr. the length of both the steel and the iron tube was 55.495 in. When heated to 186 deg. Fahr. the length of the steel tube was 55.547 in., and of the iron tube 55.543 in. The tubes were put in the

same furnace, made red hot, and then dipped in water. The length was then gauged at a temperature of 46 deg. Fahr., and that of the steel tube was found to be 55.488 in., and that of the iron tube 55.492 in. Upon the process being repeated the steel tube was found to be 55.457 in. long and the iron tube 55.4885 in. A third heating and cooling brought the steel tube to 55.44075 in. long and the iron tube to 55.482 in. long. The tests of both tubes were conducted simultaneously, and every care was taken to make them exactly alike. It will be seen that the total contraction of the steel tube, after the third cooling, was 0.05425 in. and of the iron tube 0.01300 in. The steel was Siemens-Martin, such as is generally used for tubes for Admiralty boilers. The iron was B.B. quality, Scotch make. The next test was made by putting two tubes into a pair of plates bolted together. Each hole was rimered with the same bit, and each tube end turned to the same gauge and rolled by the same man. The diameter of the tubes was $2\frac{3}{4}$ in., each being of the same thickness. The steel was Siemens-Martin, made to Admiralty requirements. The iron was B.B. quality, ordinary Scotch make. The whole was heated in a furnace to a dull red heat, and dropped into water of about 100 deg. Fahr. After the structure was cooled it was found that the steel tube was so slack in the hole that when water was poured upon the joint it ran between the plate and the tube. The iron tube was tight.

These experiments, coming from so good an authority, are worthy of every consideration at the present time. It may be said that the treatment was violent and that tube ends and tube plates in actual boilers do not become heated even to a dull red. That is true under ordinary conditions, but when the furnace temperature is extremely high and when the circulation is much impeded, it is possible, as we pointed out in an article on this subject which appeared in our issue of May 20, that the tube ends may become heated to an extraordinary degree. At any rate, Mr. Blechynden's experiments emphasize the desirability of making an effort to determine what that temperature may be. In our article we suggested the use of a pyrometer of the nature of Le Chatelier's pyrometer, if such an instrument could be

found; for the Le Chatelier pyrometer is more suitable to higher temperatures than those to which tube ends are, it is to be hoped, ever subjected. Since our article appeared we have learnt that Mr. Callendar, of Cambridge, was engaged with the late Mr. Willans in following out experiments exactly on these lines at the time of the latter gentleman's untimely death. The instrument to be used in this case was Mr. Callendar's improved electrical resistance pyrometer, his method of winding the platinum wire on strips of mica, in place of a clay cylinder, having rendered Siemens' instrument available for the purpose. If these experiments are discontinued through Mr. Willans' death, it will be one more of the many losses that engineering science will have sustained through the death of one of its brightest ornaments. We hope and believe, however, that there are left those who have the power and the desire to follow up such an investigation, and we trust Mr. Callendar will soon find another efficient coadjutor.

Mr. Blechynden has also been engaged in a series of very interesting experiments on the transmission of heat through metallic substances, and his conclusions in some respects, we believe, tend to upset generally received opinions on this subject. The details are not yet available for publication, but so far as we understand they tend to show that the resistance increases rapidly with increase in thickness when a given substance of plate has been reached. For instance, up to $\frac{1}{2}$-in.-plates the rate of transmission for the same difference of temperature is approximately equal; but after that thickness is reached, the resistance to the passage of heat from the furnace gases to the water in the boiler appears to rise rapildy, so that between $\frac{1}{2}$ in. and $\frac{3}{4}$ in. there is as great a difference as 25 per cent.; the surfaces being clean in all cases. Mr. Blechynden's experiments also tend to show that the rate of transmission appears to increase very much more rapidly than in proportion to the difference of temperatures. For heat directly received from a fire it is, for a wide variation of temperature, approximately as the square of the difference. It has also been shown by these experiments that the rate of transmission is the same, for

the same difference of temperature, whether heating or evaporating water. It will be seen that Mr. Blechynden's experiments are of a very interesting nature, and we hope before long to be able to lay them before our readers in detail. The prosecution of research of this kind is of the greatest value to the engineering profession; and, we may add, that at establishments where it is carried on, purchasers have the best guarantee, perhaps, that can be given that their orders will receive intelligent consideration likely to lead to good results; and, even beyond this, that the management will take a pride in turning out creditable work; for a good investigator is always a conscientious worker.—"Engineering" (London), June 24, 1892.

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NORMAND'S TUBULOUS BOILER ON *TORPEDO BOAT NO. 149.*

The following data and the cut of the Normand boiler are abstracted from the "Engineer" (London), of July 15th:

*Torpedo Boat 149* of the French Navy was built and engined by M. J. A. Normand, the well known torpedo-boat builder, and early in May of this year was subjected to the usual trials, when her performance was remarkably good.

The hull dimensions are: Length on water line, 118 feet; beam, 13 feet 1½ inches; depth, 8 feet 8½ inches; draught forward, 3 feet 5 inches; amidships, 3 feet 10 inches, and aft, 4 feet 2¾ inches; area of immersed midship section, 34.5 square feet; displacement, 75 tons.

The engines drive a single screw, and are of the triple-expansion type, with cylinders 16, 23 and 31½ inches in diameter by 18 inches stroke. These engines are provided with all of M. Normand's latest improvements, including the compression safety valves on the cylinders; filters to prevent the entrance of grease into the boiler, an evaporator to supply deficiency of feed, and a feed-water heater worked by steam from the second intermediate receiver. This last appliance is an improvement on those previously used by M. Normand, the coefficient of heat transmission being augmented in the ratio of 2½ to 1, as compared with the previously-made heaters. The result is that the temperature of the feed is increased, when the boat is running at full speed,

from 194 degrees Fahr., the highest temperature secured in previous boats, to 272° Fahr., the temperature of the steam being 289° Fahr., corresponding to an absolute pressure of 57 lbs. per square inch.

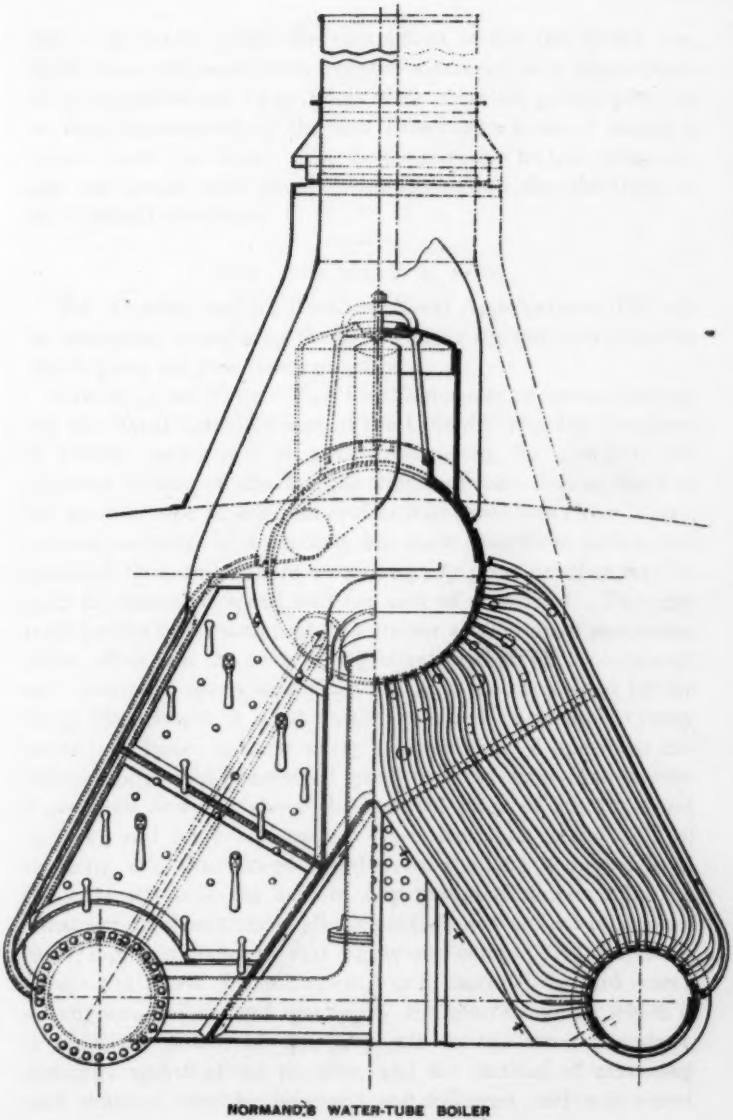
The most remarkable feature in the boat, however, is the boiler, which was designed by M. Normand. The French authorities do not want the details made public, but we are permitted to give a transverse section, which will serve to make clear the general principles of its construction. The tubes are of copper and brass. The downward circulation is maintained, as in the du Temple boiler, by pipes of large diameter at the back end of the boiler, uniting the upper receiver with the two lower horizontal water tubes. The grate surface is 35.5 square feet, and the heating surface 1,895 square feet.

[It might as well have been said that the downward circulation is maintained in the same manner as in the Thornycroft boiler, of which this one appears to be a copy, leaving out some of the specially good features of the latter. As a matter of fact, almost every successful tubulous boiler secures the down current in exactly this way.—EDITOR.]

The results obtained during the trials of this boat are eminently good. The first trial consisted of three runs over the measured mile. The second was a run of two hours without slacking speed. The following are the averages:

| | Measured mile. | Two hour run. |
|---|---|---|
| Revolutions per minute, | 325.95 | 339.17 |
| Average speed per hour in knots, | 23.58 | 24.51 |
| Steam pressure, Boiler, lbs. | 171 | 178 |
| Steam pressure, H.P. cylinder, " | 154 | 169 |
| Steam pressure, I.P. " " | 72 | 79 |
| Steam pressure, L.P. " " | 17 | 18 |
| Vacuum, ins. | 26 | 26.3 |
| Air pressure in fire room in inches of water, | 2.4 | 2.5 |
| Temperature of feed, degrees Fahr., | 269 | 273 |

During the two hours' run at full speed the fuel burned was 2,280 kilos (5,050 lbs.), during which time the boat covered



NORMAND'S WATER-TUBE BOILER

nearly 49 knots. After the completion of the two hours' run, three more runs were made over the measured mile, when speeds of 23.05, 26.06 and 23.40 knots were obtained, giving with the average obtained during the first three runs a mean of means of 24.642 knots per hour. The boiler gave no trouble whatever, and was found, when opened for examination after the trials, to be in perfect condition.

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NEW SHIPS FOR U. S. NAVY.

The following extract from the Naval Appropriation Bill will be interesting as showing the provision for the two new ships for which plans are now being prepared:

*Increase of the Navy.*—That for the purpose of further increasing the Naval Establishment of the United States, the President is hereby authorized to have constructed, by contract, one armored cruiser of about eight thousand tons displacement of the general type of armored cruiser numbered two (New York), to cost, exclusive of armament, not more than three million five hundred thousand dollars, excluding any premium that may be paid for increased speed and the cost of armament. The contract for the construction of said cruiser shall contain provisions to the effect that the contractor guarantees that when completed and tested for speed, under conditions to be prescribed by the Navy Department, it shall exhibit a speed of at least twenty knots per hour; and for every quarter knot of speed so exhibited above said guaranteed speed the contractor shall receive a premium over and above the contract price of fifty thousand dollars; and for every quarter knot that such vessel fails of reaching said guaranteed speed there shall be deducted from the contract price the sum of fifty thousand dollars. In the construction of said vessel all the provisions of the act of August third, eighteen hundred and eighty-six, entitled "An act to increase the Naval Establishment," as to material for said vessel, its engines, boilers, and machinery, the contract under which it is built, the notice of and proposals for the same, the plans, drawings, specifications therefor, and the method of executing said contract, shall be observed and followed, and said vessel

shall be built in compliance with the terms of said act, save that in all its parts said vessel shall be of domestic manufacture. If the Secretary of the Navy shall be unable to contract at reasonable prices for the building of said vessel, then he may build such vessel in such Navy Yard as he may designate.

Also one sea-going coast-line battle ship, designed to carry the heaviest armor and most powerful ordnance, with a displacement of about nine thousand tons, to have the highest practicable speed for vessels of its class, and to cost, exclusive of armament and of any premiums that may be paid for increased speed, not exceeding four million dollars.

And in the construction of said battle ship, the provisions of the act of August third, eighteen hundred and eighty-six, entitled "An act to increase the Naval Establishment," shall be observed and followed in the same manner that the provisions of said act are applied to the construction of the armored cruiser herein authorized; and in the contracts for the construction of said battle ship, such provisions for minimum speed and for premiums for increased speed and penalties for deficient speed may be made, subject to the terms of this act, as in the discretion of the Secretary of the Navy may be deemed advisable.

### THE ATLANTIC RECORD.

*Fast Time by the City of Paris on its Western Passage.*—New York, July 27.—The Inman Line steamship *City of Paris*, which sailed from Liverpool on the 20th instant and Queenstown on the 21st for New York, and arrived here early this morning, beat the record for western trips across the Atlantic. The time of her passage across the ocean was five days, fifteen hours and fifty-eight minutes, actual time. The following is an abstract of the log of the *City of Paris*. The voyage was the twenty-sixth westward one:

July 21 left Daunts Rock light ship at 2.04 P. M. (Greenwich mean time); July 22, 478 miles, light breezes, smooth sea; July 23, 501 miles, strong southerly breeze; July 24, 519 miles, moderate to light winds; July 25, 504 miles, moderate to light winds, slowed four and three-quarters hours on account of fog; July 26,

520 miles, moderate to light winds; from noon July 26, 263 miles to Sandy Hook light ship; July 27, arrived at Sandy Hook light ship at 1.02 A. M. (6.02 A. M. Greenwich mean time).

On July 24th, 519 miles were run and on July 26th, 520 miles; both runs beat the record.

The record for fast western voyages across the Atlantic from Queenstown was held until to-day by the White Star steamship *Teutonic*, her time being five days, sixteen hours and thirty-one minutes. The *City of Paris* beats the record by just thirty-three minutes. If she had not had to slow down on July 25th, she would have beaten the record down to five days and twelve hours.

The total distance run was 2,785 knots, giving a mean speed of 20.48 knots for the trip.

It is scarcely necessary to remind the readers of the JOURNAL that while the average speed of 20.48 knots for the entire trip is correct, it is not the speed through the water uninfluenced by wind or current, as is the case with the trial-trip speeds of our fast cruisers. As a matter of fact, for about two days in each voyage, the fast Atlantic liners take a course where they get the benefit of a current which is sometimes equal to nearly a knot per hour. Had this been the case with the *Paris* on her late trip, the mean speed would have been only 20.19 instead of 20.48. Of course, the comparisons made are fair enough between vessels running over the same route and under the same circumstances, but when comparisons are instituted with naval vessels, it is well to bear these things in mind.

The *Paris* did not long hold the record for the fastest single day, as the *Teutonic*, on a trip ending just a day after that of the *Paris*, made from noon to noon 528 miles, which the daily papers call an average speed of 22 knots, because from noon to noon is ordinarily 24 hours. In the case of the *Teutonic*, however, as the record was on the last day, when nearly in the latitude of New York, where a degree is only 45.6 knots instead of 60, the gain in time for a run of 528 knots is 0.77 of an hour, so that the real time was 24.77 hours, making the real speed 21.32 knots

per hour. And, as already stated, we know nothing as to the effect of favorable currents and breezes on that day.

This fast run was made the occasion of considerable comment in the daily papers unfavorable to the *Columbia* (long known as the *Pirate*), for which a sea speed of only 21 knots is claimed, but these writers forget that the high speed was for a single day only, and in all probability partly due to favoring currents, as the engines of these large vessels run with remarkable uniformity. The 21 knots of the *Columbia* are expected to be made through the water, so that if she encounters favorable currents her speed will run up just like the liners.

The first week of this month seems to have been remarkable for record breaking, as the *Umbria* made a trip in 5 days 22 hours and 5 seconds, the first time that a single-screw ship has come under six days. The best previous record for a single-screw ship was 6 days 1 hour and 50 minutes, made in September, 1889, by the *Etruria*.

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### THE FAILURE OF NAVY BOILERS.

["Engineering," May 20, 1892.]

It is a matter for satisfaction to us, in writing on this subject, that the manufacturers of the boilers which have recently failed in the Navy hold so high a position in their profession that nothing we may say can be supposed to be casting any reflection upon either their skill as designers, or the quality of their workmanship. Moreover, as no complaint is made of undue restrictions on the part of the Admiralty, we may exclude the personal factor in approaching this subject. In fact it is not a question of this or that manufacturer or designer. So many eminent marine engineers are connected with the failures which have occurred that we may assume a new phase of engineering science has come to the front and some fresh principles have to be evolved, or rather fresh applications have to be made of old principles. That was the case a generation back, when we went to 60 lbs. pressure with surface condensation and salt water in the boilers. Then, for a time, it seemed as if there was no way to be seen by which we could escape our troubles, and it was

thought that we should have to give up so ambitious a flight as the excessive pressure of 60 lbs. to the square inch, and revert to 30 lbs. and the comfortable box boilers. Now we have something approaching three times sixty as our pressure, but with fresh water and forced draft. Of old it was found that careful and intelligent application of accumulated experience solved the problem, and so it will be in the present case.

There is, however, a Nemesis about this incident of leaky tubes which engineers, and especially marine engineers, will do well to remember and profit by. In place of making the apparatus in which steam is generated their first study, as it logically should be, many engineers have too much neglected the boiler, working for the most part by rule of thumb, and leaving important questions of detail largely to the foreman boiler maker and average draughtsman, whose empirical knowledge has been thought sufficient to meet the case. There are, of course, exceptions; and so far as workmanship is concerned the application of machine tools, especially hydraulic appliances, has enabled immense strides to be made of late. Neither ought we to forget the advances that have been made in materials. The mild steel of the present day is almost an ideal metal for the boiler maker, and indeed seems to leave little to be desired. It is to the design of the boiler that too little attention has been paid, marine engineers as a body appearing content to lean on the metallurgist and machine tool maker for their improvements. As we have said, there are exceptions, but it would be invidious to specify them; although we feel compelled to say a word for the torpedo boat builders, who have set a good example in this respect, as in many others. In fact the success of the two pioneer firms in this branch of engineering has been very largely founded on a proper appreciation of the necessity of good boiler practice. Mr. Thornycroft has struck out a new line, and has now pinned his faith to the pipe boiler. Mr. Yarrow, on the other hand, appears inclined to be true to his early love, which has served him so well from the first; but we know, from the contribution he made last year to the Institution of Naval Architects, in how thorough a manner he has studied

the problem. It may be stated, in connection with this subject, that the locomotive marine boiler, which Messrs. Yarrow & Co. placed in No. 80 torpedo boat, is one of the most powerful boilers in the Royal Navy, supplying, as it does, steam for 1,700 to 1,800 indicated horse power. The trial trip of this boat was made about four years ago, and the vessel has been in commission ever since, although this does not, of course, mean the boat has been continuously running; but we believe we are correct in stating that this boiler has never given any trouble from leaky tubes.

Perhaps the most general reason assigned for leaky tubes is the arrangement of a common combustion chamber in the double-ended boiler. This question we partly dealt with in our article on navy boilers, on page 355, *ante*.* The first two of H. M. ships, fitted with the common combustion chambers in double-ended boilers did very well on their trials. It would appear from this that boilers with common combustion chambers can be run with forced draft. On the other hand, a large number of the ships that have most notably failed have had double-ended boilers and common combustion chambers. There is one reason why the common combustion chamber should be more trying to the tube ends than the combustion chamber that serves only the furnace or furnaces of one end of the boiler. In a return-tube boiler when there is a water-space at the back of the combustion chamber, the flame will impinge on the surface of that water space, and the temperature of the gases may thus be largely reduced before entering the tubes or striking against the back-end tube plate; the gases will, as it were, have their sting taken out of them before attacking the most delicate part of the boiler's anatomy. To what this reduction of temperature may practically amount is a matter upon which we can only form surmises, as we know so little about furnace temperatures; at any rate the dividing of common combustion chambers by a transverse firebrick wall has not been found a satisfactory expedient; although, for that matter, there have been troubles enough

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with boilers where the water space division has been used. In a long double-ended boiler the total expansion of the furnaces, tubes and combustion chambers on the one hand, and the boiler shell on the other, is naturally greater than in the shorter single-ended boiler, but here again we want information as to the temperatures of the metal in the furnaces, tubes, and combustion chambers, and the boiler shell respectively. Such information should not be difficult to obtain in a rough manner, but with sufficient accuracy to form a good guide to a conclusion. Alloys of different melting points could be used, and it is possible that, if a continuous record were required, an instrument of the nature of the Le Chatelier pyrometer might be employed, although the latter has hitherto been used for higher temperatures than have yet, it is to be hoped, been reached by the metal of a boiler even in the neighborhood of the back ends of the tubes.

Doubtless in the two matters of expansion and circulation, or the neglect of them, has rested the secret of most of our boiler troubles. The difference in temperature between saturated steam at the very highest tension used, and the furnace gases, is so great that one cannot believe that water, which should be practically the same temperature, can be in contact with the tube plate and tube ends. Experiments have been made, in order to determine this point by inserting a tube through a stuffing box in the boiler shell, and drawing off the contents of the boiler from any part by sliding the tube in or out. The experiments, however, are not likely to prove very instructive, carried out in the way that was adopted in making them. Water, at any considerable pressure, and of a temperature due to a pressure of steam at the temperature, would not appear as water on being released in the atmosphere. If only steam be present in the neighborhood of the tube ends, it may be at times superheated steam. One can conceive that the heat may be transmitted so rapidly to the water in the boiler, owing to the intensity of the flame, that water would be evaporated and superheated before the steam could disentangle itself from the surrounding water. We know that a bubble of air will adhere below water to the

side of a vessel, and, although the circumstances are by no means parallel, the fact may serve the purpose of illustration. In water-tube boilers the water sometimes gets on the top of the steam; one boiler of this class was designed specially on this principle, and the question arises whether, in Navy boilers crowded with tubes only having an inch space between them, the same effect is not produced. What probably happens is that steam and water alternate amongst the tubes, more especially at the tube ends; steam is formed, hangs to the surfaces at first and increases in volume until the water breaks through and the steam finds its way upwards through the wilderness of tubes. If the period of these alternations of steam and water contact is at all extended, one can understand how hard it must be on the joints between the plate and tube, and there is quite enough to account for the water pouring out at the furnace mouth faster than it can be pumped through the feed valves.

The particular water-tube boiler to which reference has just been made was possible, so far as it was possible, only in virtue of its powerful circulation. In it convection was entirely destroyed, and we may take it as an axiom of boiler design that as we impede convection so must we provide other means of circulation. The torpedo-boat builders use locomotive boilers open beneath the grate, and they have no trouble with their tube plates, or at any rate comparatively no trouble, remembering the enormous evaporative duty they get. With locomotive type of boilers with wet-bottom fireboxes there has, however, been a good deal of trouble, and on some future occasion we may deal with the probable reasons for this. Meanwhile the question arises whether something more cannot be done to conduct the water to the tube plate. In the case of the *Vulcan* sixteen rows of tubes, thirteen in each row, were removed in order to improve the circulation. In some of the cruisers that have been successful in regard to their boilers under forced draft, guide plates were used to assist circulation, and with good effect. In one case we are informed the circulating plates were taken out with a marked decrease in the easy steaming of the boilers.

Mr. Yarrow holds, or at any rate suggests, that the leaky tube

difficulty is due to the great thickness of the tube plates, and he has brought forward some very cogent arguments, supported by experimental data, to prove his case. The tube plates of the *Vulcan's* boilers are $\frac{13}{16}$ in. thick, but Mr. Yarrow would, we should think, have no hesitation in making them $\frac{1}{2}$ in. thick only. His contention is that the tube plate, stayed as it is by the tubes, is really the strongest part of the boiler. Mr. Yarrow, in the locomotive boilers of his torpedo boats, and such boilers as that in No. 80 boat, puts in no stay tubes, a fact which speaks strongly as to the support afforded by plain tubes properly expanded. It is surprising how great is the holding power of tubes properly expanded. Experiments in this direction have been made in America by the United States Naval Engineers, when it was found that out of a number of brass tubes of $2\frac{1}{2}$ in. diameter, simply expanded into a tube plate, the average holding power was over 20,000 lbs., the minimum being 6,000 lbs. In some experiments made for us by Professor Kennedy, and in other experiments made for Messrs. Yarrow, it was found that in some cases the holding power of the expanded tube was stronger than the tube itself, and in all cases it was sufficient to constitute the tube an efficient stay. In these experiments, however, the racking to which a boiler is subject, due to unequal expansion and contraction, is not represented, and this is a factor which must not be lost sight of. One thing may be said, however, that a tube will either be a stay or a safety valve; that is, a safety valve so far as explosion is concerned, but it is not convenient, to say the least, to have a number of safety valves discharging into the furnaces, although we have the time-honored device of a fusible plug as a precedent. Taking all points into consideration, however, the case against stay tubes is a very strong one. We know in the case of Lancashire boilers the trouble that arises from excessive rigidity through carrying the gusset stays too deep. Perhaps, now that the Admiralty have taken to inquiring and experimenting on the boiler question, they will think Mr. Yarrow's suggestion of a thin tube plate worthy of trial.

The material of which the tubes are made has been pretty generally considered to be an important factor in causing the

leakage of tube ends; indeed, at the present time it appears to be uppermost in the minds of many engineers, and some go so far as to say that the using of steel tubes accounts for the whole mischief. Facts do not quite bear this out. The *Medea's* and *Medusa's* boilers had iron tubes. Their trials were carried through without leakage, but the tubes leaked as the boilers cooled down. The iron tubes of the *Australia* and *Galatea* did not leak on trial, but the success of these may be attributed to other reasons than the material of which the tubes were made. The *Vulcan's* tubes are of steel, as are those of the *Royal Sovereign*. We are not able to say exactly in what way iron is supposed to be superior to steel for boiler tubes. Some say the shrinkage of an iron tube is less than in one of steel, and we understand that one well-known marine engineer has made experiments in this direction, but what the results are we do not know, except that we have heard generally that the iron tubes show themselves better able to withstand the effects of forcing at high pressures.

The trouble from leaky tubes has led to the introduction of a device for the protection of the tube ends from actual contact with the hot gases. This is the application of a protecting ferrule, which has a trumpet mouth end very much turned over. The ferrule is of considerable length, so that it projects inwards some way beyond the tube plate. It also projects outward beyond the tube, and the bell or trumpet-mouth end, turning back until its edges touches the tube plate, thus forms a shield to the contact joint between the tube and tube plate. Some of these ferrules were fitted in a few of the tubes of the *Royal Sovereign's* boilers with very good results, none of these tubes showing signs of leakage. Since then we have heard of a trial made with the *Barracouta*, which is pronounced a remarkable success. A number of trials have also been made at Chatham, and we hear it is "practically impossible to make tubes leak when these ferrules are fitted, however much the combustion may be forced." That we can believe, but after all such a device can only be of the nature of an expedient. It is a part of the design that there shall be an air space under the turned-over ends of the ferrules, so that they

get very little protection from the water in the boiler, supposing it to be there, and it would not be long before they burnt away, to say nothing of the chance of them falling out or being knocked out when sweeping tubes. In spite of this, the plan may be of some value. A war ship is required only to steam at her highest speed, with forced draft, on an emergency. That emergency should arise once at least in the life of every vessel in Her Majesty's Navy—namely, on her full-power trial. The other emergencies would be called forth by actual battle. War vessels cannot in the present day, any more than in the past, be expected to be put to their ultimate purpose without risk of damage, and one of the most prominent risks, until we improve our boiler practice, will be the risk of causing the tubes to leak. We can understand a captain saying in the course of an action, "If I increase my speed to the utmost my vessel is capable of attaining, I shall probably sink my opponent;" or, may be, in the case of encountering a far more powerful foe, "I shall escape with my ship." That would warrant a great deal of leaky tube defect; just as a commander of old would risk his masts to put his foe at a disadvantage. Now it is not probable that a sea fight will often take place without there being some notice of its likelihood, and in that case the protecting ferrules might be shipped and would well repay their cost, even were they very speedily to disappear in fulfilling their functions. It is evident, therefore, that what would be quite inadmissible in a merchant vessel, the normal condition of which is to be always doing its best, is quite a legitimate thing for a war vessel that is only called on for a supreme effort on rare occasions. Nevertheless, the use of ferrules in this way is of the nature of a temporary expedient, and cannot but be offensive to the well-balanced engineering mind.

After all it is the question of weight and space which is at the root of all our troubles with leaky tubes. Given boilers big enough and the crooked places would be made straight without further trouble. But we cannot afford to follow this easy policy. Naval supremacy, like commercial supremacy—both essential to our national existence—is of the nature of a race, there can be no resting by the way. We must always be struggling to keep

our lead, or others will take it from us. At present the struggle has assumed a very unpleasant phase. Speed is essential in the design of a war vessel, and speed means light boilers. Engineering knowledge is being more widely spread abroad. Competition amongst navies is becoming keener. The old easy ways will no longer serve, and the engineer-in-chief to the Navy may rest assured his berth is going to be no quiet haven of rest. If he makes it such he is not fit for the post. In engineering practice advance and change mean uncertainty, and this in spite of the more extended application of scientific principles. Improvements in material and in the design of machinery have given us marine engines which are capable of using large volumes of steam, and we now have the more difficult task of designing boilers to supply that steam. In a ship these boilers must neither be too heavy nor too bulky. Urging the furnace draft is an old expedient, but it seems to offer a partial solution to the difficulty of generating large quantities of steam with a small weight of boiler. That there are difficulties in the application of the system is now very obvious; but these difficulties must be overcome. If we do not master them some one else will, and it would be a shame to the marine engineers of this country, with their wide experience and unrivalled resources, if some other nation, less well equipped than ourselves, pass us in the race.

We have no patience with those sensational newspaper critics who describe this matter in their biggest type as a "most serious Naval scandal," and speak of professional officials, who, at least, are honestly doing their best, as "a set of blunderers." It is really a thing upon which we may be largely congratulated, that the Engineers of the Admiralty have got themselves into their present very unpleasant position. That we say seriously. The nation will have to pay for some new boilers, but that is a small matter compared to knowing that we have energetic and ambitious men in charge of the steam department at Whitehall; that there is an atmosphere different to the pleasant old sleepy ways, when we were content with 14 knots if we could not get 15 without a little risk and too much wear and tear of cerebral tissue.

As we have said, the question of comfortable boilers is a question of weight and space, but not altogether so. For instance, the *Sans Pareil* and the *Victoria* made very good trials. The mean collective horse power of the two ships was 14,363 indicated on the four hours' forced draft trials with a steady 2-in. air pressure on the water gauge the whole time. In the *Royal Sovereign* the mean collective horse power was 13,300 indicated on the three hours' run (the figures reached 14,300 as a maximum), the air pressure starting at about ½ in. and gradually working up to 2 in. The three ships have the same number of boilers, eight each, of the same general design, although there is a difference in weight. Each of the two former ships' boilers weigh 30 tons 10 cwt. (without fittings), and the water in each of them 16 tons 1 cwt. The *Royal Sovereign's* boilers each weigh 32 tons, and the water in each of them is 15 tons 7 cwt. There was no trouble with the *Victoria* and *Sans Pareil's* boilers, whilst the *Royal Sovereign* had to be content with a three hours' run on account of leaky tubes. There is, however, one noteworty difference in the two cases. The *Victoria* and *Sans Pareil's* boilers have iron tubes whilst those of the *Royal Sovereign* are of steel. Whether this affected the result is a matter which has to be settled. The weight of each of the *Vulcan's* four double-ended boilers, without fittings, is 45 tons 16 cwt., and the water in each weighs 26 tons 13 cwt. To this must be added the auxiliary boiler, which weighs, without fittings, 21 tons 3 cwt., and contains 12 tons 10 cwt. of water. On her best trial the *Vulcan's* engines gave off 7,577 indicated horse power with 0.71 in. of air pressure. In connection with this point we may draw attention to the fact that the mean result of the eight hours' natural draft trial of the boilers of the *Royal Sovereign* is as high as the four hours' forced draft trials of the first and second-class cruisers, as the following will show. The first-class cruisers have boilers with a total heating surface of 25,400 ft., and during the four hours' forced draft trial their engines indicated 12,400 horse power, equal to 2.03 ft. of heating surface per indicated horse power. The air pressure was .725 in. on the water gauge. In the *Royal Sovereign* the total heating surface

## Table giving Particulars of British Naval Boilers.

| Ship | *Conqueror.* | *Australia* and *Galatea.* | *Medea* and *Meduza.* | *Marathon* & *Magicienne.* | *Vulcan* |
|---|---|---|---|---|---|
| Type of boiler | Single-ended R. T., six flat-sided, and two circular. | Double-ended R. T., one common combustion chamber. | Double-ended R.T., with one common combustion chamber with firebrick wall up center. | Double-ended R.T., one common combustion chamber, firebrick division. | Double-ended R. T., common combustion chamber with firebrick wall, also one smaller for auxiliary. |
| Number of boilers | Eight. | Four. | Four. | Four. | Four. |
| Diameter and length | Six 12 ft. 2 in. X 9 ft. 6 in. X 15 ft., two 12 ft. 4 in. X 9 ft. 6 in. | 14 ft. 8 in. X 16 ft. 9 in. | 12 ft. 2 in. X 18 ft. 2 in. | ..... | 14 ft. 1 in X 17 ft. |
| Length of grate | 7 ft. 6 in. | 5 ft. 8 in. | ..... | 7 ft. 4 in. | 7 ft. |
| Area | 558 ft. | 495 ft. | 525 ft. | 535 ft. | 600 ft. |
| Heating surface, Tube | 11,050 ft. | 13,400 ft. | 12,096 ft. | 11,771 ft. | 13,830 ft. |
| Heating surface, Total | 13,340 ft. | 15,000 ft. | 13,680 ft. | 13,471 ft. | 15,960 ft. |
| Steam space | ..... | 2,760 cubic feet. | 1,608 cubic feet. | 1,824 cubic feet. | 2,412 cubic feet. |
| Number of tubes | ..... | 2,880 | 2,808 (688 stay). | 2,528 (520 stay). | 3,251 (331 stay). |
| Diameter " | 3 in. | 2¾ in. | 2½ in. | 2½ in. | 2½ in. |
| Length " | 6 ft. 6 in. | 6 ft. 6 in. | 6 ft. 9½ in. extreme. | 7 ft. 3½ in. | 6 ft. 8½ in. |
| Total number of furnaces | 24 | 24 | 24 | 24 | 27 |
| Diameter " | six 3 ft. 4 in., two 3 ft. | ..... | 3 ft. 1½ in. | 3 ft. 0½ in. | 3 ft. 7 in. |
| Area through tubes | ..... | 90 square feet. | 74.4 | 67.25 | 85.80 |
| Material of " | brass. | iron. | iron. | ..... | steel. |
| Thickness of metal in tubes | .137 in. | .165 in. (stay .187 in.) | .135 in. (stay .187 in.) | ..... | .135 in. (stay .187 in.) |
| Pitch of tubes | ..... | 3¾ in. | ..... | ..... | 3½ in. |
| Ratio grate to heating surface | 23.9 | 30.3 | 26.1 | ..... | |
| Type of engines | Vertical compound, two sets. | Horizontal triple, two sets. | Vertical triple, two sets, | Horizontal triple. | Vertical triple, two sets. |
| Diameter of cylinders | 54 in. and two 70 in. | 35 in., 51 in. and 77 in. | 33.5 in., 47 in., 74 in. | 34½ in., 51½ in., 76½ in. | 40 in., 59 in and 88 in. |
| Stroke | 3 ft. | 3 ft. 8 in. | 3 ft. 3 in. | 3 ft. | 4 ft. 3 in. |
| Specified weight of machinery | ..... | 771 tons. | ..... | 650 tons. | |
| | | tons. cwt. qr. | | tons. cwt. qr. | tons. cwt. qr. |
| Weight of engines | ..... | 270 10 0 | ..... | 218 6 2 | |
| " water in condensers | ..... | 11 0 0 | ..... | 8 0 2 | |
| " propellers, &c. | ..... | 65 0 0 | ..... | 37 16 2 | |
| " boilers with fittings | ..... | 320 10 0 | ..... | 257 2 1 | 220 12 2 |
| " water in boilers | ..... | 110 3 0 | ..... | 102 19 0 | 119 3 2 |
| " auxiliary machinery | ..... | 23 0 0 | ..... | 25 11 3 | |
| Total | ..... | 800 3 0 | ..... | 649 17 0 | |
| | | *Australia.* / *Galatea.* | *Medea.* / *Meduza.* | *Marathon.* / *Magicienne.* | |
| Weight of boilers without fittings | ..... | 193 tons. / 193 tons. | ... / ... | ... / ... | |
| Air pressure for draft | 1.50 in. | 1 65 in. / 1.21 in. | 2.23 in. / 1.9 in. | 2.37 in. / 2.2 in. | .71 in. |
| Steam pressure | 65 lb. | 132 lb. / 136 lb. | 149 lb. / 149 lb. | 146 lb. / 148 lb. | 145 lb. |
| Revolutions per minute | 106 | 118 / 115 | 139.4 / 143 | 144 / 143.5 | |
| I.H.P. | 5,342 | 8,922 / 9,653 | 9,185 / 9,435 | 8,785 / 9,280 | 7,577 |
| I.H.P. per cwt. of boiler with water | ..... | 1.034 / 1.121 | .... / .... | 1 22 / 1.288 | 1.115 |
| I.H P. per cubic foot of boiler | .492 | .788 / .853 | 1.087 / 1.116 | ... / ... | .716 |
| Cubic feet steam space per I.H.P. | ..... | .309 / .286 | .175 / .170 | .2076 / .1965 | .318 |
| Sq. ft. total heat. surface per I.H.P. | 2.497 | 1.681 / 1.554 | 1.489 / 1.450 | 1.533 / 1.452 | 2.106 |

was 19,600 ft., and the indicated horse power during the natural draft trial, with an air pressure of .39 in. water, was 9,640; this is equal to 2.02 ft. of heating surface per indicated horse power. Of course, these comparisons of heating surface and power developed are partial and unsatisfactory, but we can only work with the tools we have. To arrive at any just conclusion we should discard indicated horse power and base our estimates on water evaporated; but information on that point is, of course, not at our disposal. Now that the Marine Engine Research Committee of the Institution of Mechanical Engineers have shown that meters can be satisfactorily used on shipboard for measuring feed, it is to be hoped that further information on this important matter will be forthcoming.

As an appendix to this article we give, on the opposite page, in tabular form some of the particulars we have gathered in the course of our inquiry on this subject. The table is not so complete as we could wish, but there is great difficulty in gathering information on these subjects. As a rule contractors are liberal enough, but the Admiralty looks with extreme disfavor on the publications of any details concerning the machinery of Her Majesty's ships. Why this should be, we are at a loss to understand. It is not from any motive of national policy, for foreign countries have no difficulty in getting full information; in fact any contracting firm will willingly supply a foreign Navy with machinery such as that which they have placed in any of Her Majesty's ships. We know the professional officers are not averse to publication of technical matter, and we can only suppose the desire for secrecy is to be attributed to that parliamentarian influence at Whitehall, which, some how or other, appears always to work for ill in matters connected with the Navy.

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### LEAKY BOILER TUBES.

Dr. A. C. Kirk has sent to "Engineering" the following interesting account of experiments bearing on this question, which was published in the issue of July 15th:

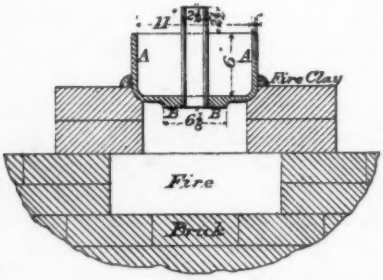
To the Editor of "Engineering."

SIR: Although little may be known of the arrangement of Admiralty boilers, it is notorious that much trouble has been caused by leakage of tubes under forced draft, a phenomenon that does not show itself in boilers in the merchant service when so worked.

Several causes have been suggested, and amongst others Mr. Yarrow suggested that the leaky tube difficulty may be due, at least in part, to the thickness of the tube plates. This led me to make some experiments on the subject, which although they are not of a sufficiently refined nature to be absolutely conclusive may not be without interest to many of my brother Engineers.

For the sake of simplicity the experiments were made in an open boiler over a smith's fire. The experiments did not represent the actual condition of a boiler on board ship; firstly, because the temperature of the fire upon the end of the tube and on the tube plate was higher than it would be even with forced draft; secondly, the experiments were made under the atmospheric pressure, or, in other words, the boiler was open to the atmosphere at the top; thirdly, there was only one tube and perfect access of water to the neck of it, and to the inner surface of the tube plate.

The apparatus I used is shown in the annexed sketch. A A was a malleable iron dish, supported on brickwork with a fire below blown by a couple of tuyeres—in fact erected on one of the smithy hearths and blown by the smithy blast. Fixed in the bottom of it was a steel tube $2\frac{1}{2}$ in. in diameter, part of a tube got for the boilers of H. M. S. *Gibraltar*. The lower end of this tube was turned, extended through the thickness of the tube plate, and fixed by being expanded in the tube hole in the usual way.




Half into the tube and half into the tube plate three plugs of

fusible metal were inserted, one of tin, one of lead and one of antimony.

When the experiments began the part of the plate into which the tube was fixed was 2¾ in. thick. At each successive experiment the thickness of this part representing the tube plate, was reduced by turning a certain amount off it.

As the water evaporated it was simply made up by slowly pouring in a little at the open top.

I will now describe the successive experiments in order, commencing with the plate 2¾ in. thick.

*Experiment 1.*—After the water was boiled for half an hour, the dish was lifted off the fire with the water in it, and the outer portion of the thick part of the bottom or tube plate was found to be red hot.

The tin and lead plugs were melted out, but the plug of antimony was intact.

*Experiment 2.*—The thickness of the portion of the plate in which the tube was fixed was reduced to 1¾ in. by 1 in. being turned off it, and three new plugs of tin, lead and antimony fitted as before.

The basin was replaced on the brickwork and subjected to the full heat of the fire for three-quarters of an hour.

When lifted off the fire, the water still in it, the plate was not visibly red hot, but the tin and lead plugs were melted, though the plug of antimony was not.

*Experiment 3.*—The thick part of the plate in which the tube was fixed was now reduced to 1¼ in., and plugs put in same as before, the vessel replaced on the brickwork and submitted to the action of the fire for three-quarters of an hour.

On being removed it was found that the tin plug was fused, but both the lead and antimony remained quite sound.

*Experiment 4.*—This trial was a simple repetition of the last, the only difference being that a small quantity of oil was added to the water.

On the basin being lifted off the fire both the tin and lead plugs were found to be fused. This is remarkable, inasmuch as

when the water was emptied out of the basin no traces of decomposed oil were visible.

*Experiment 5.*—The thickness of the bottom of the vessel was now reduced to 1 in. and three plugs inserted same as before.

In this case, when the vessel was removed from the fire, the tin plug was found to be completely melted, the lead and antimony plugs remaining quite sound.

*Experiment 6.*—The thickness of the part of the bottom in which the tube was fixed was this time reduced to a mean of $\frac{13}{16}$ in., and two tin plugs and one of lead inserted in the same way as before.

As in the previous trials, the vessel was placed on the fire for three-quarters of an hour, and on lifting it off one of the tin plugs was found to be melted, the other not, and the lead plug was perfectly sound.

It so happened that the turner in reducing the thickness of the bottom left it $\frac{3}{4}$ in. at one side and $\frac{15}{16}$ in. at the opposite side. The tin plug which melted was in the part that was $\frac{15}{16}$ in. thick, while the tin plug in the part $\frac{3}{4}$ in. thick was not melted.

In all these cases, except No. 4, the water was pure Loch Katrine water.

In No. 1 experiment we can say in round figures that the temperature of the end of the tube was about 1,000 deg.

In No. 2 experiment the temperature was over 600 deg. and under 1,000 deg.; perhaps we shall not be far wrong if we put it down as about 700 deg.

In the third experiment the temperature was between 450 deg. and 600 deg.—probably nearly 600 deg., as when it was repeated with a little oil present (Experiment 4), the temperature was somewhat over 600 deg.

In the fifth experiment the temperature was probably about 500 deg.

In the sixth experiment, where the tube plate was $\frac{15}{16}$ in. thick, the temperature must have been about 440 deg., and where it was $\frac{3}{4}$ in. thick, below that.

In all these cases the temperature of the water round the neck of the tube was 212 deg. In a boiler under a pressure of 160

lbs. the temperature of the water would be 370 deg., and the temperature of the ends of the tubes, under the conditions of the experiments above, would in each case be raised by 158 deg.

But we know that the condition of the supply of solid water round the necks of the tubes is very far from being fulfilled in an ordinary boiler—how far we cannot say, but the temperature may from that cause be very easily raised still higher.

Although the conditions under which these experiments have been made are not of a sufficiently definite nature to draw an exact conclusion from, they would indicate $\frac{3}{4}$ in. as about the limit of thickness of a tube plate that can be used with any propriety, and this is borne out by experience.

I may mention that in a preliminary experiment with this apparatus the tube was merely driven a tight fit into the bottom of the vessel, and the vessel simply placed on the fire, so that the flame could escape round the outside as well as through the central tube.

When lifted off the fire the thick part of the bottom was quite red hot round the outside, as at *B B*, though not immediately round the tube. There was sufficient heat in the thick bottom to keep the water boiling for some time after being lifted off the fire, and to assist in cooling it I put a small quantity of cold water in, with the effect of stopping ebullition for a few seconds and causing a leakage round the bottom of the tube, which stopped as soon as ebullition recommenced. After the tube was expanded tightly in the bottom, the addition of a little cold water, as above, caused no leakage. Of course the water was under the atmospheric pressure only. The portion of the length of tube covered by the thickness of the tube plate was no doubt hotter than the tube plate, for, while the tube plate is heated on one side and cooled on the other, the heat is applied over the whole surface of the tube corresponding to the thickness of the tube plate.

ALEXANDER C. KIRK.

Lancefield House, Glasgow, July 9.

In the next issue Mr. A. F. Yarrow, who has himself made elaborate experiments on this subject (an abstract of his paper before the Institute of Naval Architects was published in the

JOURNAL, Vol. III, pp. 229–237), pays a compliment to Dr. Kirk for the value of his experiments, and particularly for making the results public. He adds, however, that his own experiments and extended experience have convinced him that the minimum thickness of tube sheet may safely be put at one-half inch rather than three-quarters. He says: "We have tried many experiments bearing on the subject, and have invariably found a benefit as regards overheating with each successive reduction in the thickness, which is only reasonable to expect, owing, I believe, to there being, in the case of the thin plate, a less distance for the heat to pass through, and consequently a less difference of temperature between the two sides." He adds: "If copper be adopted for tube plates, its high conducting power avoids this overheating. I believe this to be the reason why locomotive engineers in this country [England], with few exceptions, select this metal."

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### THE HARVEY CARBONIZING PROCESS.

The Harvey process of case hardening which has been so successfully applied to giving a hard surface to armor plates, is carried out as follows: The plate to be heated is made of mild steel containing from 0.10 to 0.35 per cent. of carbon, and after being formed to its final shape, is laid flat upon a bed of finely powdered dry clay or sand, which is deposited on the bottom of a firebrick cell or compartment erected within the heating chamber of a suitable furnace. The upper surface of the plate is then covered with powdered carbonaceous material, which is tightly packed. Above this is a layer of sand, and over the sand is laid a heavy covering of firebricks. The furnace is then lighted and raised to a temperature sufficient to melt cast iron, and this heat is maintained for a greater or less period, according to the amount of carbonizing to be effected. About 120 hours are said to be necessary for a plate 10½ inches thick. On removal from the furnace such a plate is found to have had the composition of its upper surface changed. At a depth of about three inches from this surface the percentage of carbon has been raised by about 0.1 per cent., which increases progressively as

the outer surface is neared, when the amount of carbon may rise to 1 per cent. It is said that this process, though, as will be seen, it resembles the ordinary cementation process, does not cause any blistering of the surface of the plate. The inventor attributes this to the high temperature at which the process is carried on; it is, however, suggested that the absence of blisters may be due to the homogeneity of the metal used, which, unlike the wrought-iron bars used in the cementation process, is free from cinders.

## SHIPS.

### UNITED STATES.

*Columbia* (*Cruiser No. 12*, long known as the *Pirate*).—This vessel was launched from the Cramp shipyard July 26th. A description of this vessel was published in the JOURNAL for August, 1890, Vol. II, p. 409, but as some important changes have been made, the following account is given:

Length between perpendiculars, 412 feet; beam, 58 feet; mean draught, 22 feet $7\frac{3}{4}$ inches, corresponding to a displacement of 7,350 tons. Coal capacity at this displacement, 750 tons; total coal capacity, 2,000 tons, on a displacement of 8,600 tons. The main battery consists of one 8-inch B. L. R. aft and two 6-inch B. L. R. forward, on upper deck; eight 4-inch R. F. G., twelve 6 pounder R. F. G. and four Gatlings. The protective deck is 4 inches thick on the slopes and $2\frac{1}{2}$ inches elsewhere. There will be two pole masts fitted for fore-and-aft sail. The contract speed is 21 knots for four hours in the open sea, which it is expected will be obtained for about 21,000 I.H.P., while it is estimated that the maximum speed will be about 22 knots on 23,000 I.H.P.

There will be three triple-expansion engines, each driving a separate screw, and each in a water-tight compartment. The

outside screws will occupy nearly the same position as in a twin-screw ship, except that the shafts point slightly upward from a horizontal line, so as to raise the screws as much as is safe with certainty of good immersion, and that they are placed about fifteen feet further forward than would be the case with twin screws. The central screw occupies the usual position of a single screw, but the shaft is inclined slightly downward. This disposition of the screws has been made to insure an adequate supply of water to each, and to prevent, as far as possible, the propeller races from interfering. As viewed on a central athwartship plane in projection, the circles of the screw discs are all clear of each other.

The cylinders are 42, 59 and 92 inches diameter by 42 inches stroke, and are of the usual inverted vertical type. The revolutions for full power are expected to be 129. Piston valves will be used for all the cylinders, driven by Stephenson double-bar links; there will be one valve for the H.P., two for the I.P. and four for the L.P. cylinder, those of the I.P. and L.P. being interchangeable. The framing will consist of cast-steel inverted Y-columns at the back and cylindrical forged steel columns at the front. The bed plates are of cast steel. The crank shafts are in three interchangeable and reversible sections, and all shafting is of hollow forged steel.

The condensers are cylindrical and of composition, each having about 9,474 square feet of cooling surface, making an aggregate for all three of 28,422 square feet. The air pumps are single acting and twin; that is, there are two pumps for each condenser, each driven by a simple engine, but the two connected by a beam and with but one set of valve-motion gear. The engines are arranged to exhaust into the condenser or either receiver. The circulating pumps are centrifugal, two for each condenser, driven by independent engines. There are two auxiliary condensers connected to the auxiliary exhaust main and to the discharge pipe from the evaporators.

The propellers are of manganese bronze, two right-handed and one left-handed.

There are eight main boilers of the double-ended return-tube

type; six are 15 feet 9 inches in diameter and two 15 feet 3 inches; each has eight corrugated furnaces, the diameter in the larger boilers being 40 inches and in the smaller 39 inches. The boilers are all 18 feet long. There are also two auxiliary boilers 10 feet 1¾ inches in diameter by 8 feet 6 inches long. The working pressure for all is 160 lbs. The total grate surface is 1,522 square feet and the total heating surface 49,248. The main boilers are arranged in four groups of two each, with four smoke pipes.

There are the usual feed and other auxiliary pumps, blowers, evaporators, workshop machinery, &c.

*Texas.*—Was launched at the Norfolk Navy York, June 28th. A brief description of the vessel will not be out of place, since the one given in the JOURNAL was in Vol. I, over three years ago.

The *Texas* was designed by the late William John, a distinguished English naval architect, in a competition instituted by the Navy Department. At the time of the award, Mr. John was the manager of the Barrow Shipbuilding Co., and it was claimed by that company that the price, $15,000, should be paid to them. At all events, Mr. John left their employ, and was succeeded by the late A. D. Bryce-Douglas, under whom the detailed plans were worked out. Some changes in the details were made after the plans were received in this country, but the main features are as originally designed.

The *Texas* is a twin-screw armored battle ship with a belt of armor for water line protection. Length on water line, 290 feet; beam, 64 feet 1 inch; mean draught, 22 feet 6 inches; displacement, 6,300 tons; there are two military masts, but no sail. The expected speed is 17 knots. The armor belt, which is 12 inches thick with 6 inches of wood backing, protects the magazines and the machinery; it extends 2 feet above and 4 feet 6 inches below the water line. The protective deck, which is worked over the armor belt, is 3 inches thick throughout.

The main battery consists of two 12-inch and six 6-inch B. L. R., and the secondary battery of twenty-four rapid-fire and machine guns. The 12-inch guns are in two turrets, one at each end of the vessel and on opposite sides; one of the 6-inch

guns is placed forward and the other aft in the middle line on the same deck as the turrets, while the others are in sponsons on the main deck. There are six torpedo tubes, one in the bow, one in the stern, two below water through the side forward, and two above water through the side aft.

The engines are of the usual inverted vertical type and triple-expansion, and are expected to develop 8,600 I.H.P. on trial. The cylinders are 36, 52 and 78 in. diameter by 39 in. stroke, with a piston speed of 800 feet per minute. Each engine is placed in a separate water-tight compartment. The cylinders are all steam jacketed. The condensing surface is 12,924 square feet. There are four cylindrical boilers, double-ended, each having six 39-inch corrugated furnaces. The boilers are 14 feet in diameter and 18 feet long, designed for a working pressure of 150 pounds. The total grate surface is 532 square feet, and the total heating surface 16,912 square feet. The forced draft is on the closed fire-room system. The total weight of the machinery is given as 816 tons.

Great delay has occurred in both hull and machinery from non-delivery of material on time, and the machinery has been further delayed by the burning of the boiler shop, which compelled the rejection of all the boilers when they were nearly completed and the building of new ones. A strike at the works also caused delay. The hull was built at the Norfolk Navy Yard, and the machinery is building by the Richmond Locomotive and Machine Works, of Richmond, Va., whose contract price is $634,500. This includes all the hydraulic machinery, as well as that for propulsion.

*Marblehead.*—This vessel, formerly known as *Cruiser No. 11*, was launched at the shipyard of Harrison Loring, South Boston, on August 11th. The machinery is building by the Quintard Iron Works, of New York, who have already completed it in their shops, and are now proceeding rapidly with the work of erection on board.

FRANCE.

*Dupuy de Lôme.*—The trials of this large cruiser, which began early in June, were awaited with unusual interest on account of

the fact that she is the first large triple-screw cruiser to be completed. Owing to an unfortunate accident to one of the boilers, which will be referred to later on, the trials were not completed.

On the 26th of October, 1887, orders were given to the authorities at the Brest government arsenal for the construction of the hull of the *Dupuy de Lôme*, by the then Minister of Marine, Monsieur Barbey. At the same time the orders for the propelling machinery were given to the Société Anonyme des Ateliers et Chantiers de la Loire, by whom the three sets of triple-expansion vertical engines, with which the ship is fitted, have been constructed. The first keel plates were laid on the blocks in July, 1888, and the vessel has thus been about four years in building.

Mild steel, subjected to the usual government tests, has been used throughout in the construction of the vessel, and a protective deck of this material is fitted at the water line, dipping below it at the sides and ends of the hull, but rising above it at the center line of the ship for the greater part of the length. A strong steel ram has been provided, and proves a powerful addition to the ship's offensive qualities. The ceremony of launching was carried out on October 27th, 1890, the vessel having been over two years on the stocks. The principal dimensions are:

| | |
|---|---|
| Length, . . . . . | 364 feet 2 inches. |
| Beam, . . . . . | 51 feet 6 inches. |
| Draught (aft), . . . . . | 24 feet 7 inches. |
| Displacement, . . . . . | 6,174 English tons. |

The engines, three in number, are designed to indicate a collective H.P. of 14,000 under forced draft, from which power a speed of twenty knots per hour is anticipated. Each engine drives one screw; these are situated one aft of the other two and at a greater depth. All the three propellers are of the same diameter and material—bronze; they are three-bladed and solid. The weight of the machinery is given as 1,202.5 tons.

There are ten main boilers of the low cylindrical or "straight through" type and two return-tube boilers for auxiliary purposes, all fitted with corrugated furnaces. The working pres-

sure is about 160 lbs. The smokepipes are elliptical and 53½ feet high above grates.

The armament consists of four 19-cm. (7.48 inches) B. L. R.; six 16-cm. (6.3 inches) B. L. R.; eight Hotchkiss R. F. G.; eight Hotchkiss revolvers, and four torpedo tubes. The four 19-cm. guns are mounted, one forward, one aft, and one on each side amidships, the latter on sponsons; all these guns are on the upper deck. The six 16-cm. guns are mounted on the deck below, four firing directly ahead or on the broadside, and two directly astern or on the broadside. The lighter armament is distributed partly over the upper deck and partly in the double tops on the two military masts, which serve not only as ammunition hoists but also give access to the tops, no shrouds or other rigging being provided. The torpedo tubes are one forward, one aft and one on each broadside amidships. The protective deck is 10 cm. (3.94 inches) thick, and the sides of the vessel above the water line also have armor of this thickness.

The total cost of the vessel is estimated at about $2,000,000, of which $585,000 is for machinery and $165,000 for armament.

The trials were to take place near Brest, and on June 9th a preliminary run of several hours was made with the engines going at 90 revolutions, giving a speed of over 16 knots. No attempt was made to push matters, and, as everything worked well, the vessel proceeded to the buoys for adjusting compasses. On the 20th, the vessel went out for her full power trials. The engines were gradually worked up to about 80 turns, giving nearly 16 knots, and, everything being in good condition, the fire rooms were closed, forced draft started and the speed gradually increased, with the view of reaching 110 turns, which were expected to give the designed speed of 20 knots.

Suddenly* there was a bad case of "back draft" in the after fire room, the flames coming out into the fire room. This caused the extinction of the electric lights there, leaving the place in total darkness. At the same time a glass water gauge broke, and the steam and water, added to the flames, caused a panic. The men (there was no officer present) lost their heads completely,

* The accounts do not give the hour or the speed then maintained.—EDITOR.

and a wild rush was made for the air-tight door. One man, thinking he had hold of the handle, opened the lower gauge cock on one of the auxiliary boilers, and the hot water from this scalded those who had not already been. Fortunately, the chief engineer, hearing the noise, opened the door, and the wounded were carried out. It appears that some twenty men were badly burned or scalded.

The first press reports received in this country were as wild as well could be. They stated that the head of one of the boilers had blown off, but engineers knew, of course, that this was absurd, as such a rupture would probably have caused the explosion of all the boilers and the complete wreck of the vessel.

In some of the accounts in the French papers something is said of leaky tubes and also of a stay or brace having pulled out. From these statements, and the intense back draft, it would seem that possibly one of the stays to the combustion chamber may have pulled out. A commission of officers is conducting an investigation, and the real cause will not be known until their report is made public.

Our account of the details of the accident is from "Le Yacht," which vouches for the accuracy of the statement of what actually occurred in the fire room.

It may be added that the preliminary run was so successful that no doubt was entertained of securing 20 knots.

This accident also points to the importance of having self-closing valves on the glass water gauges and of having at least a few oil lamps lit. It also suggests that such an accident would not have had such disastrous results in an open fire room, although the case of the *Concord's* burst steam pipe shows that where there is a great outrush of steam it makes little difference whether the bulkhead doors are open or closed, so small an opening being wholly inadequate to relieve the large amount of steam.

*Bugeaud.*—The keel plates were laid in June at the Cherbourg arsenal of a new second-class cruiser for the French Navy. This vessel, named the *Bugeaud*, is similar in design to the *Chasseloup-Loubat* and the *Friant*. The principal particulars of this

cruiser are: Length, 308 feet 4 inches; beam, 43 feet 8 inches; mean draught, 20 feet 8 inches; displacement, 3,647.5 tons.

The hull, constructed entirely of steel, is fitted with a protective deck for its entire length. There are two propellers, driven by engines of a total I.H.P. of 9,000. The maximum speed expected is 19¼ knots per hour. A supply of 575 tons of coal can be carried in the bunkers.

The artillery of the *Bugeaud* consists of six 16-centimeter breech-loading rifles; four quick-firing 10-centimeter breech-loading rifles; eight of 47-millimeters and twelve of 37-millimeters, the 47-millimeter and 37-millimeter guns being of the Hotchkiss type. The ship will be further armed with two torpedo-firing tubes.

It is estimated that the cost of the *Bugeaud* will be 1,542,000 dollars, this amount being divided as below for the various parts of the work:

| | |
|---|---|
| For materials of hull, . . . | $451,000 |
| For workmanship in hull, . . | 414,000 |
| For engines and boilers, . . . | 452,000 |
| For artillery, torpedoes, &c., . . | 225,000 |
| | $1,542,000 |

It is expected that this ship will be advanced by 21 per cent. of its total construction during the present year.

*Dragon.*—Towards the end of last March there was launched from the shipyard of Messrs. Normand, at Havre, a first-class seagoing torpedo boat, to which the name of *Dragon* was given. The length of the *Dragon* is 42 meters, or 137.8 English feet; her total displacement is 117½ tons. There is one propeller, driven by one set of triple-expansion engines, developing an I.H.P. of 1,400, from which it is expected to obtain a speed of 21 knots per hour. There is bunker space for about 16 tons of coal. The armament consists of two tubes firing Whitehead torpedoes, and two quick-firing Hotchkiss guns of 47 millimeters.

*Corsaire.*—One of the last orders given out by Monsieur Barbey, the ex-minister of Marine, for vessels for the French Navy, was to the Société des Chantiers de la Loire. This was for a

torpedo boat of unprecedented speed as regards vessels of the French Navy. The new boat should be completed in November next, and will be named the *Corsaire*. The length is 164 feet, the tonnage 150 tons, whilst a speed of 25½ knots per hour is guaranteed. In addition to the torpedo-discharging tubes, the *Corsaire* will be armed with two Hotchkiss revolvers of 37 millimeters.

*The Shipbuilding Programme of the French Government, 1893.*—The shipbuilding programme of the French Government for 1893, as at present accepted, provides for the laying down of eight vessels, without counting torpedo boats, the fleet of which it is nevertheless proposed to increase.

It was at first proposed to commence the construction of a first-class armor clad line-of-battle ship, but for the reason that the French Navy is at present notoriously deficient in the number of modern cruisers in comparison with the number of large ships, this first proposition was abandoned and a programme providing for the construction of the lighter vessels introduced. These are classed as follows: Two first-class cruisers, three second-class cruisers and one third-class cruiser, one torpedo gunboat and one gunboat. As regards torpedo boats, seven first-class sea-going boats and nine coast defense boats of the first class will be commenced during the coming year.

Government arsenals will receive orders for the construction of only two of these eight vessels, namely, one cruiser of the second class and one of the third class, the rest of the work being given out to private shipbuilding firms. The second-class cruiser is of the same design as the vessels of the same type now in hand, namely, the *Bugeaud*, *Chasseloup-Loubat*, and *Friant;* it will have a length of 308.4 feet, a displacement of 3,647.5 tons, whilst the total I.H.P. of its two triple-expansion engines under forced draft will be 9,000, from which a speed of 19.25 knots per hour is looked for. The maximum amount of coal the vessel will be able to carry is put down as 587 French, or 577.8 English tons.

The artillery consists of six quick-firing 16-cm. (6.3 in.) guns, four quick-firing 10-cm. (3.9 in.) guns, eight Hotchkiss guns of

47 millimeters, and twelve Hotchkiss revolver guns of 37 millimeters. The estimated cost of the vessel is $1,480,000.

As regards the third-class cruiser, it will have a length of 321.3 feet, and a total displacement of 2,254 tons. The maximum power of the propelling machinery is specified at 6,600 I.H.P. and the speed expected is 20 knots per hour. Its armament consists of four 14-cm. (5.51 in.) guns, two of 10-cm. (3.9 in.) guns, four of 47 millimeters, and two revolvers of 37 millimeters. All these arms are of the quick-firing type. The total cost is estimated at $870,000.

The remaining six vessels are, as has been said above, to be contracted for and built by private firms. The plans of the two first-class cruisers are not yet complete, the principal particulars, however, will approximate to the following: Total displacement, 7,248 tons; I.H.P., at maximum speed, 13,400 horses; the maximum speed, 19 knots. They will each receive as armament two guns of 24 centimeters (9.44 in.), eight quick-firing guns of 14 centimeters (5.51 in.), ten of 47 millimeters and six of 37 millimeters. The cost is expected to be about $3,000,000 for each ship.

One of the second-class cruisers is identical in design with the cruiser of the same class, to be built by the Government, the dimensions throughout being the same. The other second-class cruiser will have a length of 305.11 feet, and a displacement of 3,528 tons. It is intended to give the engines a force of 9,000 I.H.P., which should be sufficient to give the vessel a maximum speed of 19 knots per hour. The offensive power of the ship consists of four quick-firing 16-cm. (6.3 in.) guns, ten of 10 centimeters (3.9 in.), also of the quick-firing type; six of 47 millimeters and four of 37 millimeters, in addition to torpedo firing tubes, firing Whitehead torpedoes. The cost will approximate $1,500,000.

The torpedo gunboat will have the same dimensions and characteristics as the *Cassini*, namely, displacement, 906.5 tons; maximum engine power, 5,000 I.H.P.; speed, from 21½ to 22 knots; coal capacity, 107.8 tons. The armament is light, and consists of one quick-firing 10-cm. (3.9 in.) gun; three of 65

millimeters and four of 37 millimeters. The estimated cost is $540,000.

The plans of the gunboat are due to Mons. Normand, the successful torpedo boatbuilder of Havre. It will be 183.73 feet long and will have a total displacement of 614.46 tons. The maximum power expected from the engines is 850 I.H.P., which should give a speed of 13 knots per hour. The coal carried is 71.54 tons. The guns are: Two quick-firing of 10 centimeters, four of 65 millimeters and four of 37 millimeters. The cost is expected to be about $250,000.

Plans of the seven sea-going torpedo boats have not yet been fully prepared, but it has been decided that the speed demanded shall be 23½ knots for the first four and 24½ knots for the following three. The armament carried will be two quick-firing Hotchkiss guns of 47 millimeters. The cost of the first four is put down at $120,000, and of the other three at $146,000.

The nine coastguard torpedo boats will have a length of 118.1 feet, and a displacement of 78.4 tons. The engine power of 2,300 horses will, it is expected, give a speed of 23½ knots per hour. Each boat will be armed with two Hotchkiss revolvers of 37 millimeters.

Of the two cruisers to be constructed in the Government arsenals, that of the second-class will be laid down at Cherbourg, and the other, the third-class cruiser, in the Government dockyard at Rochefort.

*River Gunboat.*—Of all the unexpected types of war vessel which have ever been developed, the stern-wheel gunboat seems the strangest. At first sight nothing would appear more unfitted for fighting purposes than a stern-wheeler—a tea tray with a flying deck—nevertheless these somewhat ungainly-looking craft have points which enable them to perform military operations that would be impossible for any other class of vessel. Their great virtue is their shallow draught. We all remember the humurous American announcement that one of these boats would run "wherever there was a heavy dew," and indeed some of the wooden stern-wheelers of America were marvels of light wooden structure, but they were very weak. So far as the hull proper of

a wooden boat is concerned, there is less strength in a stern-wheel boat than in any other form. The perfectly flat bottom would hardly hold together under its own weight, and the sides being low give but small vertical flange to supply stiffness. For this reason stern-wheelers have to be trussed in some way, and this trussing is generally taken advantage of to support a raised flying deck, which then forms the other member to the girder, being either the extension or compression member according to the loading.

An advantage of the stern wheel, as compared to side wheels, is that no additional width is required for the propelling apparatus; and yet another good point is that the hull goes first, as a pioneer, and protects the wheel from floating logs. It is a fact, too, that a stern-wheel boat will travel in less water than a side-wheeler, even if the hulls were made of the same form and the floats were given the same immersion below the still-water line. A boat steaming at any speed brings after it a considerable wave, and there is a corresponding hollow at the sides of the boat. The stern wheel dips its floats in the most favorable position, namely, in the crest of the wave created by the passage of the hull; in the side wheel the position is reversed. This one point alone is sufficient to turn the scale in favor of the stern wheel for shallow water navigation.

In England we do not build stern-wheelers of wood, but of that material which nature seems to have supplied to man as especially the very proper thing for the construction of floating vessels—namely, mild steel. With this material, and by a proper consideration of the resultant of forces, English engineers have designed boats of remarkably shallow draught and equally remarkable for their strength of structure. Perhaps the most noteworthy of all these vessels is that which has just been constructed for the French Government by Messrs. Yarrow & Co., who have been most closely identified with this class of vessel, and indeed the design and construction of them has largely been centred at the Poplar yard, from whence the stern-wheel gunboat originated. It will be remembered that about two years ago Messrs. Yarrow built for our government two stern-wheel

gunboats, the *Mosquito* and *Herald*, when we had a little difference of opinion with Portugal. We wanted these boats in a hurry, and they were turned out by the builders in a remarkably short space of time. In the French vessel, however, they determined to beat their own record, for the promise was made to have the vessel ready for shipment in thirty-six days, or, if tested afloat in the Thames, in eight days more. The boat was wanted to go up country to chastise the natives of Dahomey, and in such matters it is evident, to quote the lawyer's phrase, "That time is as the essence of the contract." Not having a suitable craft on their navy list, the French Government applied to French builders, but the best promise they could get in regard to time was four months, whilst other builders required longer periods up to ten months. As, after so long a period of time, the natives of Dahomey might fail to recognize for what misdemeanor the chastisement was administered and the corrective effort be therefore lost, the French Government applied to Messrs. Yarrow, and the result has been the boat under notice. In general design the boat is similar to the *Mosquito* and *Herald*. Her length is 100 feet, the breadth 18 feet, and the draught with steam up 18 inches. The speed was to be 10 miles an hour, and the carrying capacity equal to 400 troops.

The hull is composed of seven sections or pontoons, each of which will float of itself. The weight of one of these pontoons is about 2¼ tons, and therefore does not present any difficulty in effecting shipment. On the main deck there are two cabins, providing sleeping accommodation for three officers and eight men; the remainder of the European troops will sleep in hammocks and the native crew on deck. There is an upper deck extending from end to end of the vessel, and in about the center of its length is the captain's cabin. The steering wheel is placed forward, so that the pilot may see well ahead. Over the entire vessel there will be canvas awnings to serve as a protection against the heat of a tropical sun. The machinery consists of engines of the simplest kind, one on each side, driving direct the paddle wheel at the stern. In the bow is a boiler of the locomotive type, having a very large furnace, and of sufficient size to

supply ample steam at 150 lb. per square inch with wood fuel, which is the only kind obtainable on the rivers in West Africa. In connection with the boiler is a feed-water heater, and also a fresh-water condenser for the supply of drinking water. The latter apparatus is essential to vessels navigating African rivers, to avoid illness to European troops. Between the wheel and the stern are twin rudders working simultaneously. These are constructed of wood, so that in case of damage they can be readily repaired. The manœuvring powers of boats of this type, when properly designed, are exceptional, as they will turn in a circle the radius of which is a trifle more than their length. The armament consists of three 37-millimeter revolving cannons on the main deck, and four 37-millimeter quick-firing guns on the upper deck. These latter are well elevated, being 14 feet above the water level, thereby securing a good range over the river banks.

The order for this vessel was given on April 28, and she was launched on the morning of May 25 in a perfectly complete condition, and on the afternoon of the same day her first trial afloat on the Thames took place, thus occupying the remarkably short time of 23 working days to construct, Messrs. Yarrow having thus completed their contract in 17 days less time than they promised. The French Government had given the builders a perfectly free hand, and the wisdom of this course has been proved by the result. A transport will be sent over to convey this vessel to Dahomey.

On the official trial, which took place on Thursday of last week, in the presence of Captain Leclerc, naval attaché to the French Government, and Monsieur Revol, engineer, from Cherbourg, the speed was tested by six runs over the measured mile in Long Reach, on the River Thames, with the following results, showing a mean speed of a trifle over 10 miles an hour, wood fuel only being used:

| Time of day. | Steam pressure. | Revolutions per minute. | Time. | Speed in knots. | Mean speed. | Second mean. | Knots. |
|---|---|---|---|---|---|---|---|
| h. m. | lb. | | m. s. | | | | |
| 6 27 | 140 | 36 | 5 34 | 10.778 | | | |
| | | | | | 8.697 | | |
| 6 38 | 140 | 35 | 9 4 | 6.617 | | 8 673 | |
| | | | | | 8 619 | | |
| 6 53 | 145 | 37 | 5 37 | 10.682 | | 8 763 | |
| | | | | | 8.877 | | 8.743 = 10 07 miles. |
| 7 2 | 145 | 36½ | 8 29 | 7 073 | | 8.778 | |
| | | | | | 8 679 | | |
| 7 15 | 145 | 37 | 5 50 | 10.286 | | 8.759 | |
| | | | | | 8 839 | | |
| 7 25 | 145 | 36 | 8 7 | 7.392 | | | |

The boat was on an even keel, and the draught was 17½ inches. A trial for consumption at a speed of 7 statute miles an hour was made, and it was found that only 3¼ cwt. of wood was burnt per hour; that is to say, for every ton of wood carried the boat would steam 43 miles. The approximate loads carried on varying draught are as follows: On a draught of 24 inches a load of 21 tons can be carried; on a draught of 30 inches a load of 39 tons can be carried; on a draught of 36 inches a load of 58 tons can be carried.

On the whole, we may congratulate Messrs. Yarrow & Co. on a remarkable feat, and one, it may very safely be said, entirely without precedent, namely, the construction of a war vessel within the period of 23 working days.—"Engineering," June 3, 1892.

*Zouave.*—Twin-screw sea-going torpedo boat, completed her trials at Brest in May. She has two Oriolle boilers, a type fitted in several other torpedo boats. The contract speed was 20.5 knots, but a speed of 21.3 knots on 307 revolutions was easily maintained. A greater speed was not attempted, as there was no premium for exceeding 20.5 knots.

### BRAZIL.

*Republica* and *Tiradentes.*—On May 26th two cruisers, built to the order of the United States of Brazil, were launched from the shipbuilding yard of Sir W. G. Armstrong, Mitchell & Co., Els-

wick Works, Newcastle. The vessels were named the *Republica* and the *Tiradentes*, the former being a considerably larger war ship. The dimensions of the vessels are as follows:

| | *Republica.* | *Tiradentes.* |
|---|---|---|
| Length over all, | 226 ft. 0 in. | 173 ft. 0 in. |
| Length between perpendiculars, | 210 " 0 " | 165 " 0 " |
| Breadth, | 35 " 0 " | 30 " 0 " |
| Draught, mean, | 12 " 9 " | 10 " 9 " |
| Displacement, in tons, | 1,300 | 800 |
| Indicated horse power | 3,300 | 1,200 |
| Speed, forced draft, | 17 knots. | 14½ knots. |
| Armament, | 6 12-cm. guns. | 4 12-cm. guns. |
| | 4 6-pdr. guns. | 3 6 pdr. guns. |
| | 6 machine guns. | 4 machine guns. |
| | 4 torpedo tubes. | 2 torpedo tubes. |

CHILE.

*Presidente Errazuriz* and *Presidente Pinto.*—The *Presidente Pinto*, the second of the two sister cruisers lately built for the Chilean Navy by the Forges et Chantiers de la Mediterranée, at La Seyne, is about to leave Havre for Chile, her artillery having been placed on board in that port.

It will be remembered that great efforts were made by Señor Balmaceda, the late President of the Chilean Republic, to arm and equip this vessel during the late civil war in Chile, in his ineffectual efforts to create a fleet to oppose that which had revolted against his power. Before she was really completed, without any official trials, and with a mixed crew on board, consisting of Chileans, English, Spanish, Italians, Greeks, Turks, and possibly men of other nations, the *Pinto* was accidently run ashore by the carelessness or inability of the French pilot before she got out of Toulon harbor, having narrowly escaped from being blown on to the stern of the Greek ironclad *Spetzia*, then lying under repair at the La Seyne works. In about ten days the vessel was floated, and after visiting the ports of Genoa, Mahon, Southampton and Kiel, where the various Governments refused to allow the Armstrong guns, hastily bought for her, to be put on board,

and interfered with the engaging of a crew, she was taken to Havre by the representatives of the new Chilean Government, the civil war having come to an end, in order to have the Canet guns, originally intended for her, put on board, as well as to properly finish the hull and engines and to carry out any repairs necessitated by the rough usage she received from an inexperienced and incomplete crew. A part crew has arrived from Chile, and when this is completed by the enlistment of English and French, and certain modifications considered necessary by the Chilean engineers are carried out, the *Presidente Pinto* will leave for Chile.

The order for the two cruisers was given to the Société des Forges et Chantiers de la Mediterranée, without competition, in March, 1889, the designs having been prepared by the Society's naval architects in the shipyard at La Seyne, from the slips of which the two ships were launched, the *Presidente Errazuriz* on June 14, 1890, and the *Presidente Pinto* about two months later.

Below are the principal dimensions of the two vessels:

| | | |
|---|---|---|
| Length between perpendiculars, | . | 268 feet 4 inches. |
| Beam, | . | 35 feet 9 inches. |
| Depth, | . | 23 feet 4 inches. |
| Draught, mean, | . | 14 feet 7 inches. |
| Draught, aft, | . | 16 feet 5 inches. |
| Displacement, | . | 2,081 tons. |

The hull is built of mild steel, manufactured principally in the celebrated works of Le Creusot, and subjected to severe tests before being accepted by the Chilean commission. The frames and beams are for the most part of the ⌊ section, which is so largely used by French shipbuilders, as being cheaper and more easily worked than many other sections. There is no double bottom, but the hull below the protective deck, which extends the whole length of the vessel, is extensively divided and sub-divided into watertight compartments. As the vessels are sheathed with teak, Canadian elm and copper, the stern piece and stern frame are each of cast brass, and the rudder, which is balanced, is composed of a frame of cast brass and thick copper plates. The ship's framing is greatly strength-

ened at the bow, and this, with the solid stem piece and the butting of the protective deck against it, produces a powerful ram in each vessel.

Two masts are provided, but as only fore-and-aft sails are carried, the sail area may be regarded as insignificant. On each mast there are two military tops in which machine guns are mounted in the usual manner.

As has been mentioned above, the protective deck extends the entire length of the hull. This is built up of two thicknesses of steel plating, the total thickness varying, as shown below, in different parts of the vessel:

| | | |
|---|---|---|
| Over engines and boilers, | at center, . . | 2.36 inches. |
| | at sides, . . | 1.38 inches. |
| Elsewhere, | at center, . . . . . | 1.57 inches. |
| | at sides, . . . . . | 1.18 inches. |

A conning tower is built on the forward one of the two bridges, being protected with 3.15 inch Creusot steel armor, and in it are fitted the telegraphs, voice tubes and steering wheel.

The propelling machinery of each ship consists of two sets of horizontal triple-expansion engines, driving two three-bladed manganese bronze propellers, which are cast in one piece, the three blades being solid with the boss. The engines are placed in two watertight compartments, one forward of the other, with a watertight door between for the convenience of the engineers. They were built by the shipbuilding company in their works at Mempenti, in Marseilles, arrangements being made to drive the circulating, feed and air pumps of each main engine by means of a separate compound two-cylinder engine. The specified I.H.P., under natural draft, at 130 revolutions per minute, was 3,530, the speed demanded under these conditions being 17 knots per hour. At 5,400 I.H.P. and 150 revolutions, a speed of 19 knots per hour was looked for.

On the trials of the *Presidente Errazuriz*, under natural draft and at 140 revolutions per minuate, 3,550 I.H.P. were developed, whilst the speed of 17 knots specified was exceeded. Under forced draft, with 160 revolutions and 5,400 I.H.P., a speed of 18.5 knots was obtained. No proper official trials of the *Presi-*

*dente Pinto* were carried out, but from unofficial runs made it was judged that her speed was equal to or superior to that of her sister.

Steam is generated in four locomotive (low cylindrical) boilers, each fitted with three of Fox's patent corrugated furnaces, and working at a pressure of 160 pounds per square inch. They are situated in two compartments, one forward of the other, being placed back to back.

The distance the vessels are able to steam without replenishing their supply of coal is shown below:*

| | With normal supply of 166 tons. | With 294 tons. |
|---|---|---|
| At 15 knots, . . | 1,446 knots. | 2,550 knots. |
| At 12 knots, . . | 2,550 " | 4,500 " |

Considering their size, the vessels are well armed, the armament consisting of four 15-centimeter (5.9-inch) B.L.R. Canet guns; two 12-centimeter (4.7-inch) quick-firing B.L.R. Canet guns; four Hotchkiss quick-firing guns; four Hotchkiss revolvers of 37 millimeters (1.45-inch); two Gatlings of 11 millimeters (.43 inch), in addition to three torpedo-launching tubes for firing Whitehead torpedoes. The disposition of the artillery is as follows: The 15-centimeter guns are mounted on sponsons, two on each side on the upper deck; one 12-centimeter gun is mounted forward on the forecastle and the other aft on the poop deck. The quick-firing Hotchkiss guns are placed two on the fore bridge and two on the poop, whilst the Hotchkiss revolvers are situated two on the forecastle and two on the poop, the Gatlings being fitted in the military tops. The torpedo tubes are fitted, one right forward, one on the starboard side, and one on the port side just forward of amidships. The guns are all protected against light shot by shields of thin steel plate armor.

Both vessels are lighted throughout by means of the electric light, and two electric search-light projectors are supplied, one being mounted at each end of the upper fore bridge. The

* NOTE.—The coal endurance is too great. The real figures would probably not be three-quarters of those given.—EDITOR.

electricity is generated by two dynamos of the Gramme system, supplied by Messrs. Saulter, Harlé et Cie, of Paris.

The *Presidente Errazuriz* is at the present time in service in the Pacific, and is said to have given satisfaction.

ENGLAND.

*Jason.*—On Saturday, May 13th, the Naval Construction and Armaments Co. launched from their shipbuilding yard at Barrow, H. M. S. *Jason*, the first of three fast twin screw steel torpedo gunboats they are building for the British Navy.

The dimensions of all the three vessels are the same, viz.: Length between perpendiculars, 230 feet; breadth, extreme, 27 feet; depth, moulded, 14 feet 3 inches, with displacement of 810 tons, at 8 feet 9½ inches load draught. They are flush-decked with a forecastle forward, extending one-third the vessel's length, the officers' quarters being aft on lower deck. They have twin screws, with two sets of independent triple-expansion vertical inverted-cylinder engines, capable of developing 3,500 I.H.P., and driving the vessel at a speed of 20 knots per hour, the diameter of the cylinders being 22 inches, 34 inches and 51 inches, with 21-inch stroke. These engines are placed in separate engine rooms, enclosed by watertight bulkheads. The boilers are of steel, four in number, 16 feet long by 7 feet 8 inches diameter. They are of the locomotive (low-cylindrical) type, and each has two furnaces, the working pressure of steam being 150 lbs. The boilers are placed in two boiler rooms immediately forward of the engines, and are also enclosed by water-tight bulkheads. These gunboats have been designed for a high speed, combined with large coal capacity, the machinery and bunkers occupying nearly half the vessel's length. The engines and boilers are surrounded by bunkers with 3 feet of coal from below the load water line to the upper deck, giving some protection from shot and shell when filled. The magazines are well protected, and the hull is divided transversely and longitudinally into numerous water-tight compartments. The hulls of the vessels are constructed of Siemens steel. The latest improvements are being fitted for the handling of the ships. These include two rudders aft, which are actuated by steam and also by

hand gear, and steam windlass forward, a rifle-proof conning tower, search light, &c. The armament consists of one 4.7-inch quick-firing gun on forecastle, with a range of fire from right ahead to 40 degrees abaft the beam; one 4.7-inch gun aft on upper deck, with a fire to 45 degrees before the beam; two three-pounder guns forward under forecastle, and two amidships; also one fixed torpedo tube forward and two tubes on racks amidships for discharging Whitehead torpedoes. Each vessel will carry five boats on davits, one being a steam launch. The vessels will be rigged with two masts and fore-and-aft sails, and will have two funnels.

*Circe and Hebe.*—Two new gunboats were added to the Royal Navy on the afternoon of June 14th, by the "float out" at Sheerness yard of the *Circe* and *Hebe*. Designed by Mr. W. H. White, C. B., Director of Naval Construction, these vessels were laid down in January, 1890, and the great length of time occupied in their construction is accounted for by the delay in settling the type and power of their machinery, the Admiralty waiting until some of their earlier sister ships had been tested before coming to a decision. In the end it was decided to fit them with engines of 3,500 H.P., or 1,000 H.P. less than was at first contemplated. The principal dimensions of the *Circe* and *Hebe*, which are sister ships, are as follows: Length between perpendiculars, 230 feet; breadth, 27 feet; mean load draught, 8 feet 9 inches; weight of hull, 380 tons; displacement at load draught, 810 tons. The *Circe*, whose machinery is being made by Messrs. J. Penn & Sons, will be ready for the pennant at the close of the present financial year, while the *Hebe* will not be out of hand until the latter part of 1893, as her machinery, which is being made at Sheerness dockyard, will not be ready for her for a few months. Both vessels are to attain a speed of 19.25 knots under forced draft and 17.75 knots under natural draft. They will be fitted with electric search lights, steam and hand-steering gear, and all the latest improvements in shipbuilding science. Their armament will consist of two 4.7 inches quick-firing guns (one on the forecastle and one on the upper deck aft), four 3-pounder quick-

firing guns (two under the forecastle and two amidships), and five tubes for discharging Whitehead torpedoes.

*Gibraltar.*—Messrs. R. Napier & Sons launched from their shipyard at Govan, on April 27th, the first-class protected cruiser *Gibraltar*. The vessel is one of nine first-class cruisers building under the provisions of the Naval Defense Act of 1889. Four of this important class have been constructed at the Government dockyards, and the others by private firms. The *Gibraltar* is the third of the contract ships to be launched. The vessel is 360 feet long by 61 feet broad, and at a mean draught of 24 feet 9 inches will have a displacement of 7,700 tons. She is a flush-decked ship of high freeboard, resembling in this respect the *Australia* and *Galatea*, previously constructed by Messrs. Napier. The hull, which is of steel throughout, is sub-divided into numerous water-tight compartments. As it is proposed to employ the vessel on distant stations, where dock accommodation is often wanting or inadequate, the steel hull has been sheathed with teak planking, and will be coppered. In this way the speed will be maintained and the bottom remain clean, even though the vessel is at sea for a long period. The machinery, which has been constructed by the builders, consists of two sets of independent triple-expansion engines, with a maximum of 12,000 H.P. under forced draft, and 10,000 I.H.P. under natural draft. The estimated speeds are 19½ and 18½ knots respectively. The armament, which is exceedingly powerful, includes two 9.2 inch, 22-ton, breech-loading, rifled guns, ten 6-inch quick-firing guns and seventeen smaller quick-firing guns. The two 9.2-inch guns are mounted as bow and stern chasers respectively, and can be fought on either broadside. They also command very large arcs of training before and abaft the beam and across the keel line. The 6-inch quick-firing guns are mounted on the broadside, three on each side on the upper deck, and two on each side on the main deck. The foremost and aftermost pairs of upper-deck guns can fire parallel to the line of keel, and all have very large arcs of horizontal training. The smaller quick-firing guns are to be mounted in commanding positions on the broadside, furnishing a complete all-round defense against tor-

pedo-boat attack, and acting as valuable auxiliaries to the other guns.

All the guns on the upper deck will be furnished with strong protecting shields to shelter the crews and the mountings, while the main deck 6-inch quick-firing guns will be protected by separate armored enclosures or casemates. The *Gibraltar*, although not described as an armored vessel, carries a very considerable weight of protective material. All the vitals—engines, boilers, magazines, &c.—are situated below a strong protective deck, which has a maximum thickness of 5 inches on the slopes, and 2½ inches on the horizontal or nearly horizontal portions. This deck extends from stem to stern, and is associated with cellular subdivision and the bunker protection. A strongly armored conning tower is provided for the commanding officer's use in action, and from it he will be able to steer and direct the fighting of the vessel. The ordinary navigating station is immediately above. Strong steel protective tubes are provided for the service of ammunition from the magazines below the thin steel deck up to the decks where the guns are. In fact, the material devoted to protection would have gone far towards providing the sides with thin armor had it not been decided to dispose of the weight in a different manner. The coal supply under ordinary circumstances, and at the load draught mentioned, will be 850 tons. Provision has also been made for a larger quantity. The ship was laid down by Messrs. Napier in December, 1889, and the contract provides for her delivery in a very complete condition, with masts and rigging in place, and comparatively little to be done after her arrival at the dockyard.

## MERCHANT STEAMERS.

*S. S. El Norte*, which was launched from Newport News Shipbuilding and Drydock Company's Yard at Newport News, Va., on the 14th of June, is being built for the Southern Pacific Co., under the superintendence of Horace See, for service between New York and New Orleans.

The principal dimensions are:

| | |
|---|---|
| Length over all, . . . . | 406 feet 0 inches. |
| Length on load-water line, . . | 390 feet 3 inches. |
| Beam moulded, . . . . | 48 feet 0 inches. |
| Depth moulded to awning deck, . | 33 feet 9 inches. |
| Gross tonnage, about . . . . | 4,500 tons. |

The hull, including deckhouses, is built of iron. She has three decks and a partial orlop deck at fore end of forehold. There are ten transverse bulkheads extending up to lower deck, and four bulkheads between lower and main deck. Above the main deck there are only two bulkheads, one aft of the crew space at forward end of the vessel, and the other a few feet forward of the rudder post, leaving a continuous cargo space of 332 feet in length. There are four cargo hatches, the main hatch being 14 feet square, and six large cargo ports on each side of the vessel; six hoisting engines and seven cargo booms; steam windlass forward on main deck; working capstan above on upper deck; capstan aft, two gipsies, complete steam steering gear forward, reserve steering gear in wheelhouse aft. Officers' quarters are all in the deckhouses, unusually large and roomy and fitted up luxuriously. Her rig consists of four pole masts with mutton leg and stay sails.

The machinery consists of a triple-expansion surface-condensing direct-acting marine engine, with inverted cylinders working on cranks at angles of 120°. The cylinders are 32-inch, 52-inch and 84-inch diameter, respectively, and the length of stroke 54 inches. The pistons have no tail rods but are fitted with adjustable followers. The valves are of the piston slide variety, and

the radial valve gear is designed so that all of the valves are brought close to the cylinders and the clearances reduced to a minimum. The steam is admitted to the middle of the high and medium-pressure valves, the counter-balance pistons are dispensed with and the valve-stem stuffing boxes of these cylinders subjected only to the pressure of the exhaust steam.

The surface condenser has 6,400 square feet of cooling surface, water being furnished by an independent centrifugal circulating pump.

The crank shaft is 16 inches in diameter. The propeller is a true screw, four bladed, built up, 18 feet in diameter and 22 feet pitch. The steam is supplied by three double-ended cylindrical steel boilers 13 feet 10 inches in diameter and 20 feet 6 inches in length, having six 44-inch corrugated furnaces in each boiler, leading into one common combustion chamber.

*S.S. El Sud*, the sister ship of *El Norte*, which was launched on March 16th, made her trial trip on July 14th. With a boiler pressure of 165 pounds the engines made 73 revolutions and indicated 3,362 horses power.